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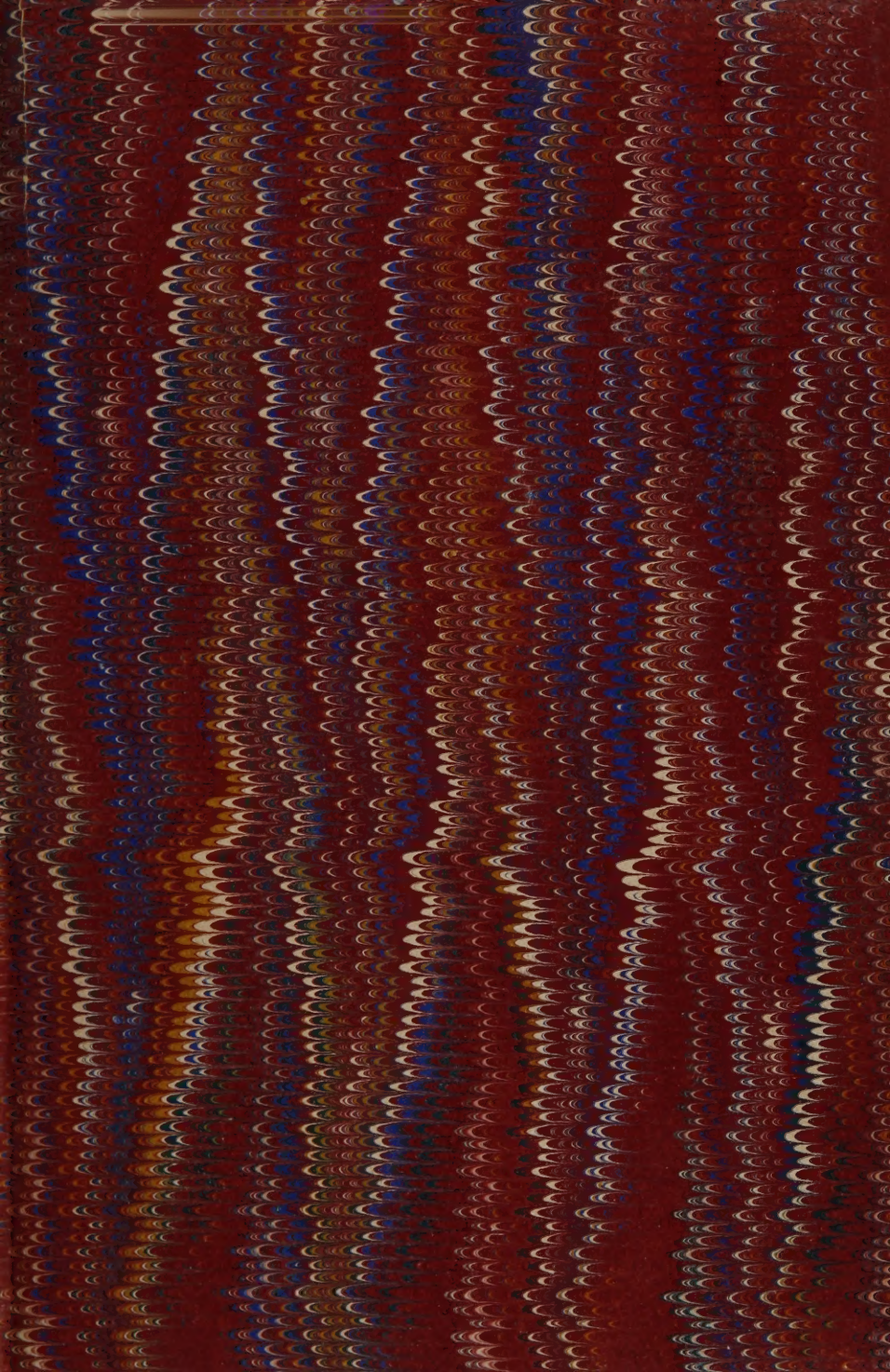
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**EXPOSITION**

OF THE

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EXHIBITION

OF THE

ATOMIC THEORY

1901

**EXPOSITION**  
**OF THE**  
**ATOMIC THEORY**  
**OF**  
**CHYMISTRY:**  
**AND THE**  
**DOCTRINE OF DEFINITE PROPORTIONS.**

BY

**WILLIAM JAMES MACNEVEN, M.D.**

PROFESSOR OF CHYMISTRY AND MATERIA MEDICA IN THE COLLEGE OF  
PHYSICIANS AND SURGEONS OF THE UNIVERSITY OF  
THE STATE OF NEW-YORK.

WITH AN APPENDIX OF CHYMICAL EXERCISES,  
BY THE PUPILS OF THE LABORATORY, &c.

NEW-YORK:

PRINTED BY GRATAN AND BANKS,

Corner of Nassau & Spruce Streets.

1819.

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*Southern District of New-York, ss.*

L. S.

Be it remembered that on the nineteenth day of October, in the forty-fourth year of the Independence of the United States of America WILLIAM JAMES MACNEVEN, of the said district hath deposited in this office the title of a book, the right whereof he claims as author, in the words following, to wit:

"Exposition of the Atomic Theory of Chymistry, and the doctrine of Definite Proportions, by William James Macneven, M.D. Professor of Chymistry and Materia Medica in the Collège of Physicians and Surgeons of the University of the State of New-York; with an Appendix of Chymical Exercises, by the Pupils of the Laboratory, &c."

In conformity to the act of the Congress of the United States, entitled "An Act for the encouragement of Learning, by securing the copies of Maps, Charts, and Books, to the authors and proprietors of such copies, during the time therein mentioned." And also to an Act, entitled "An Act, supplementary to an Act, entitled an Act for the encouragement of Learning, by securing the copies of Maps, Charts, and Books, to the authors and proprietors of such copies, during the times therein mentioned, and extending the benefits thereof to the arts of designing, engraving, and etching historical and other prints."

G. L. THOMPSON,

*Clerk of the Southern District of New-York.*



TO  
**THE STUDENTS**  
OF THE  
**UNIVERSITY OF THE STATE OF NEW-YORK.**



Gentlemen,

I have been at some pains to arrange, for your instruction, the following Exposition of the Atomic Theory and the Doctrine of Definite Proportions; and I shall consider my labour well bestowed, if the tract which I now offer you should have the effect of facilitating your acquaintance with this fundamental part of chymistry.

The demonstrations of the atomic composition of bodies have not hitherto been exhibited in a manner sufficiently plain and elementary for those persons

who begin the study, although this part of the science is already of great and early importance.

Examples have not been wanting in the laboratory of this College to shew that nothing so effectually accelerates the progress of the student, or gives so much precision to his acquirements, as a speedy initiation into the principles and details of the new doctrine.

The University of which you have the honour of being members is distinguished for the respect and favour with which it regards chymical studies; while, in our particular College, they are indispensable, being made an essential part of the medical classes.

Several well informed physicians and chymists have gone forth from our walls: You are destined to continue the honourable succession; and this school may expect to be often gratified with the

pleasing intelligence that, while you diffuse the light of its lessons, you grow, like your predecessors, in fame, in usefulness, and in fortune.

Believe me, Gentlemen,

Your sincere friend,

THE AUTHOR.





## EXPOSITION, &c.



1. It has been known, ever since chymists acquired the art of analyzing bodies, that substances always enter into chymical combination in determinate proportions. Nitrate of potash, under all circumstances and in all situations, consists invariably of 54 parts nitric acid and 46 potash, per cent. Common salt of 46 muriatic acid and 54 soda ; no matter whether the salt was taken from the sea, or from a spring, or artificially made, these proportions of the constituent parts are uniform. Carbonate of lime is always found to consist of 43·2 carbonic acid and 56·8 lime. Sulphate of barytes of 34·5 sulphuric acid and 65·5 barytes. The more rigorously has this law been examined by accurate analysis, the more conspicuous and decided have become the proofs of its reality. It is therefore universally admitted ; indeed, it is obvious, that if there was not a law of nature to determine and preserve these fixed proportions, there could be no uniformity in compound bodies: But the uniformity and fixed-

ness of the law necessarily depend on some ulterior cause which renders all other combinations impossible. Now, this cause, whatever it be, must constitute the principal basis of chymical philosophy, and well understood and rigidly applied, it would introduce mathematical precision into our chymical reasonings and conclusions. In ascending to the cause we can assign it no other residence than those elementary particles of matter which are so constituted as to be exempt from decay or change, though they are capable of being variously compounded together and separated again, so as to give origin to the perpetual transitions of elementary into organized matter; but the nature of the elements themselves is immutable; the forms only can vary. The indefatigable alchymist frequently exhausted every device and process, endeavouring, with keen research and prodigal talent, to alter the nature of matter, and transmute one species of metal into another, but he was eternally foiled in this chimerical attempt.

The productions of nature have not only succeeded one another in the same general order, but have been from the beginning invariably the same. An oak of the present time has the same general nature and the same properties, as those of all other oaks that ever existed; we find the same texture in its wood and bark; a similar disposition, in general, in its root and branches; the leaves have



the same form; the juices the same astringent power; the fruit is moulded to the same shape of an acorn, and has the same invariable property of never producing any other tree than an oak.

All this shews that the elements of bodies are permanent and unchangeable. Had they been liable to any gradual alteration or waste, the oaks of the present times, composed of those changed materials, would not be found to have the same qualities as the oaks of remote ages; and the order and course of nature, as well as the qualities of her productions would have been different from what they have uniformly appeared, and what we actually find them.

Such obvious reflections on the course of nature have, in the earliest ages of philosophy, suggested the supposition of a certain number of unchangeable elements, of which it was imagined all things were composed, and on the successive separations and reunions of which depended the decay and reproduction of all natural objects. This was the meaning of the opinion ascribed to Democritus, that all things were formed of atoms.\*

We are consequently warranted by the phenomena in assuming that the ultimate particles of matter are so

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\* Black's Lectures, vol. 2, p. 4.

perfectly hard and minute as never to wear or divide. It is only by continuing entire that the particles may form bodies of the same nature and texture in all ages. Should they wear away, or break in pieces, the nature of all things depending on them would change incessantly, and, contrary to experience and fact, there would be no permanent species of matter. But since the ultimate particles, which henceforth we shall call atoms, are indivisible and indistructible, we may be permitted to deem them also simple.

2. In the chymical combination of different substances the *atoms* of those bodies unite together, and this is what causes them to be dispersed through the whole mass. Chalk is composed of lime and carbonic acid; now, how minute a portion soever of chalk we take, we shall find it to contain both lime and carbonic acid. How minute a portion soever of water we take, we shall find it to contain both oxygen and hydrogen. How minute a portion soever of saltpetre we take, we shall find it to contain both nitric acid and potash. Hence, it necessarily follows that, in a chymical compound, of the simplest composition, every atom of one ingredient is united to one or more atoms of the other.

3. The extent of this combination is limited.—Thus, if a dilute solution of potash be added to an ounce of sulphuric acid, a point is observable, at

which the potash and acid lose their peculiar characters, the one of turning vegetable blue colours green, the other of making them red, and a liquid is left of a bitter taste, affording a bitter salt, which crystallizes in short hexangular prisms. If an additional quantity of potash be now added it effects no change in the nature of this salt, but remains distinguishable itself as potash; or if, instead of potash, there be added an excess of acid, it does not alter the nature of the salt, but is recognized, in like manner, by its own acid character. The quantity of one substance entering into chymical union is limited therefore by that of the other. To this phenomenon the older chymists, expressing the fact only, gave the name of *saturation*. And having further observed that an ounce of different acids required unequal quantities of potash for saturation, they established that the point of saturation varied with the substance, and that it was different in different bodies.

Modern chymists have given to this law the name of *definite proportion*, meaning thereby to express a fact which they have traced more extensively and correctly than their predecessors. Indeed all chymical compounds contain the same proportion of constituents with the most rigid accuracy, no variation ever taking place in this respect. The whole science of chymistry is founded on the permanency of chymical compounds.



4. Richter in his geometry of the chymical elements, gave great extension to the doctrine of definite proportions, and enriched it by a vast number of new and important observations. He observed, that, when two neutral salts, which mutually decompose each other, are mixed together, the two newly formed salts still retain the same neutral state as the two original ones from which they were formed. He drew up the results of many experiments in tables exhibiting the weight of each base, capable of saturating 100 parts by weight of each acid, and the weight of each acid capable of saturating 100 parts by weight of each base. He found that the different bases follow exactly the same order in each of the tables, and, he observed further, that the numbers in each table constitute a series which have the same ratio to each other in all the tables. Suppose, for example, that in the table representing the muriates, the quantity of potash requisite to saturate 100 parts of muriatic acid were three times as great as the quantity of alumina requisite to produce the same effect; the same thing would hold in the sulphates, nitrates, and all the other genera of salts. Three times as much potash would be required to saturate 100 sulphuric, nitric, or any other acid, as would be requisite of alumina.

These facts explain how it happens that when two neutral salts decompose each other, the new-

formed salts are also neutral, and why there is no excess of acid or base upon the one side or the other. The same proportions of bases that saturate a given weight of one acid, saturate all the other acids; and the same proportions of acids that saturate one base, saturate all the other bases. Hence, numbers may be attached to each acid and base indicating the weight of it, which will saturate the numbers attached to all the other acids and bases. This is the foundation of Dr. Wollaston's sliding rule of chymical equivalents.

5. Mr. Dalton, in 1804, turned his attention to the subject, and was struck with the small number of proportions in which simple substances are capable of uniting, and the constancy of these proportions. Thus, if we represent the weight of carbon by 75 we find that carbonic oxide and carbonic acid, the only two compounds of carbon and oxygen, are composed as follows :

Carbonic oxide of 75 carbon + 100 oxygen,

Carbonic acid of 75 carbon + 200 oxygen.

So that the quantity of oxygen in carbonic acid is to that in carbonic oxide as 2 to 1.

If we represent the weight of nitrogen by 175 we find that all the compounds of nitrogen and oxygen are composed as follows :

Protoxide of nitrogen 175 nitrogen + 100 oxygen.

Deutoxide of nitrogen 175 nitrogen + 200 oxygen,

Hyponibrous acid of 175 nitrogen + 300 oxygen.

Nitrous acid of 175 nitrogen + 400 oxygen.

Nitric acid of 175 nitrogen + 500 oxygen.

So that the quantity of oxygen in these compounds, supposing the nitrogen to remain always the same, is as the numbers 1, 2, 3, 4, 5.

Similar observations may be made respecting the composition of the metallic oxides, the chlorides, the neutral salts, and all chymical combinations with which we are acquainted.

The fortunate thought occurred to Mr. Dalton "that those proportional numbers represented the respective weights of the atoms of the combining bodies;" that bodies combine either 1 atom of one, with 1 atom of another, or with 2 atoms, or with 3, 4, 5, or 6 atoms. According to this notion, if we represent the weight of an atom of carbon by 0.75, an atom of oxygen will be 1, and carbonic oxide will be a compound of 1 atom carbon and one atom oxygen, and carbonic acid of 1 atom carbon and 2 atoms oxygen. If the weight of an atom of nitrogen be 1.75 and that of oxygen 1, then the compounds of nitrogen and oxygen are composed as follows :

Protoxide of nitrogen of 1 atom nitrogen + 1 atom oxygen.

Deutoxide of nitrogen 1 - - - + 2

Hyponitrous acid - - 1 - - - + 3

Nitrous acid - - - 1 - - - + 4

Nitric acid - - - 1 - - - + 5



The simplicity and beauty of this opinion made a speedy and strong impression upon chymists in general. Its truth is now universally admitted.\*

6. Mr. Higgins, professor of chymistry in Dublin, in a work published by him in 1789, made a near approach to the atomic theory. He delivered the composition of sulphurous and sulphuric acids, the composition of water and the compounds of oxygen and nitrogen, nearly, as they are now received. But his own experiments were too few, and there were not data enough furnished by others to supply sufficient materials for the construction of the atomic theory. During the twenty-one years that elapsed between the publication of the comparative view of Mr. Higgins and the elements of chymical philosophy by Dalton, with more industry, the former might, perhaps, have secured to himself the reputation for which he is now so solicitous; but, if liberal and candid, he will confess that celebrity without labour is neither legitimate nor attainable in the walks of science, and that the fame of a discovery belongs rightfully to him, who is not only the most sedulous, but also the first to promulgate and apply it. Without being the discoverer of the atomic theory, no man in Britain has done so much for it as Dr. Thomson; and by Berzelius and Gay

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\* Thomson, vol. 3, p. 19.

Lusac its principles have been carried as much beyond where Dalton left them, as he exceeded the scanty suggestions furnished by Mr. Higgins. It is now every where received, and constantly improving.

7. The invariable permanency of chymical compounds cannot be owing to any thing else than the union of a certain determinate number of the atoms of one constituent with a certain determinate number of the atoms of the other. The proof of this position will be more easy and striking, if we first take an example from the union of gaseous bodies, the atoms of which, unrestrained by the force of cohesion, are at liberty to arrange themselves according to their chymical affinities.

Let the compound to be investigated be water, which is known to result from the condensation of oxygen and hydrogen gases, when they are ignited together. We shall denote the atoms of oxygen which unite by  $x$ , and those of hydrogen by  $y$ , and then an integrant particle of water will, in every case, be  $x + y$ .

The numbers  $x$  and  $y$  are easily found by making an accurate analysis of the different compounds into which various proportions of oxygen and hydrogen enter. Let us take water. It is known from experiment that 100 cubic inches of oxygen gas, weigh 33.888 grs., and that 100 cubic inches of hydro-

gen, weigh 2.117 grs. If these volumes be mixed together and the electric spark passed through them, there will be a condensation of all the hydrogen and half the oxygen; so that 100 cubic inches, or 2.117 grs. of hydrogen can condense no more than 50 cubic inches, or 16.944 grs. of oxygen. But, if we mix 2 volumes of hydrogen, or 4.234 grs. with 1 of oxygen, and then pass the electric spark, there will be a complete condensation of both the gases, and a portion of water left, precisely equal to their joint weights; consequently, the weight of oxygen in water is to the weight of hydrogen in water, as 16.944 is to 2.117, or as 33.888 to 4.234, all which, reduced to their lowest terms, are as 8 to 1. Now, if water be a combination of one atom of oxygen to one atom of hydrogen, it follows that the atom of oxygen weighs eight times as much as the atom of hydrogen.

8. We may give to this reasoning a more general form by putting  $y$  for any volume of hydrogen, and  $x$  for the same volume of oxygen; then there are in water, by experiment,  $2y + 1x$ ; and since 1  $x$  weighs 16  $y$ , the constituents of water may be expressed in weights of  $y$ ; thus,  $2y + 16y = 18y$ , the whole weight of water. Supposing this 100, we have  $18y = 100$  and  $y = 100 \div 18 = 5.555$ , weight of 1  $y$ , or one volume of hydrogen; but there are 2  $y$ , or two volumes, consequently  $5.555 \times 2 = 11.110$  gives the weight of hydrogen in 100 of water.



If we subtract the weight thus found from the compound, we have,  $100 - 11.110 = 88.890$ , the weight of oxygen in 100 of water.

Now  $88.890 : 11.110 :: 8 : 1$  nearly.

9. The weight of an atom of oxygen or hydrogen may also be deduced from the specific gravity of those gases, and it is the more usual way, for the weights of equal volumes are to each other as the specific gravities. Thus, the sp. gr. of hydrogen being 0.0694, and that of oxygen 1.111. If we take  $y$  to represent the weight of any number of atoms of hydrogen in a volume, we shall have this proportion  $0.0694 : 1.111 :: y : 1.111 \times y \div 0.0694 = 16 y$ ; and if  $16 y$  equal the weight of the atoms in a volume of oxygen,  $y \times 2 = 2 y$  is the expression for the weight of an equal number of the atoms of hydrogen; but  $2 y : 16 y :: 1 : 8$ . Therefore, the atom of hydrogen is but  $\frac{1}{8}$  of the weight of an atom of oxygen.

10. Another mode of obtaining the relative weights of the atoms from the sp. gr. of their gases is to compare the sp. gr. of each gas with the sp. gr. and weight of the common standard atmospheric air; and as they are to one common third weight they will be to one another, thus:—

$1000 : 1.111 :: 30.5 : 33.888$  weight of oxygen.

$1000 : 0.0694 :: 30.5 : 2.117$  weight of hydrogen.

The numbers 1000 represent the sp. gr. of atmospheric air; 1.111 that of oxygen gas; 30.5 the weight in grs. of 100 cubic inches atmospheric air;

and 33.888 the weight of the same measure of oxygen gas.

11. The same law is observed by other elementary bodies in a gaseous state. They unite in such proportions that one volume of the gas of one combines with an equal volume of the gas of the other, or with two or with three volumes, &c. of that gas, without any intermediate fraction ; so that in these combinations one at least of the elements ought always to be considered as unity. According to the atomic theory, this means that an atom of one of the elements combines with one or more entire atoms of the other, for there can be no fraction of an atom. The fact, that in every inorganic combination one of the elements enters as unity, is founded on numberless experiments, and is a deduction from the analytical researches of some of the ablest chymists, particularly of Berzelius, who verified it in all the inorganic bodies which he analyzed.

We have seen how strikingly this law is exemplified in the union of oxygen and hydrogen gases, and that the proportion in which they combine is definite.

12. Whereas the atoms of one kind of gas repel each other among themselves, and those of different gases attract each other, it follows that when they are mixed equably, as is the case when 2 measures of hydrogen and 1 of oxygen gas are put into a tube and fired by electricity, they will most readily unite

atom to atom. Until very lately there was no combination of oxygen and hydrogen known, but that in which they exist in water; it was therefore concluded that this was the proportion in which they unite most readily and with the greatest force. Of late, a new compound of oxygen and hydrogen has been formed by Thenard, consisting of one atom of hydrogen with more atoms of oxygen. This discovery tends fully to confirm the former opinion, viz.—That the first formed combination is one of atom to atom.

13. It also follows from a consideration of the volumes in which oxygen and hydrogen gases combine, that a given bulk of hydrogen contains only one half the number of atoms that exist in the same bulk of oxygen gas.

Here it may not be superfluous to remind the student, that the density of gases differs like that of other bodies, and that under the same volume they contain unequal quantities of matter. A remarkable example of the fact is afforded by ammoniacal gas, which can be expanded, by repeated shocks of electricity, to almost twice its original bulk. Consequently, in this new state its atoms are nearly twice as distant as they were at first, and any given measure of it contains now but about half the number of atoms which the same measure contained before.

14. Out of the consideration of this difference naturally arises that of the cause which keeps



asunder the atoms of gases and of all other bodies; for, however strong we may deem their affinity, they can never touch. On the supposition that two atoms were in actual contact, their attraction for each other would not only be as great as possible, but as great as the attraction of any other body, for either of them, could possibly be; because, by the supposition, they cannot be nearer. Consequently, since bodies chemically combined can be separated, they are not in actual contact, but their distance from one another may vary in different cases, and then the force of affinity will vary with the distance. All bodies are diminished in bulk by cold; it brings their particles nearer together, which would be impossible unless they had been at some distance before they were cooled. This reduction of their volume by cold favours the idea of caloric interposed between those particles being the cause of their not coming in contact.

15. If oxygen, hydrogen, and nitrogen gases be mixed in the same vessel, and the electric spark passed through them, a combination of oxygen and hydrogen takes place in preference to a combination of oxygen and nitrogen. The reason seems to be that there is a force of attraction or affinity inherent in every atom of matter, and that in different bodies it differs in intensity.

16. When gases are made to unite, that gas which

enters into the compound in the smallest quantity in bulk is represented by 1, and then the bulk of the other constituents of the compound is 1, 2, 3, 4, &c. Here atoms and volumes are deemed to bear to each other the same exact ratio, as we have distinctly found in the example of oxygen and hydrogen gases. It is held that 2 atoms of one substance do not unite to 2 atoms of another, for this would resolve itself into atom to atom ; nor two of one to three of another, which would amount to the union of an atom of one substance to one and a half atom of another. This cannot be, since the atom is indivisible. Were it possible to divide atoms, or to form combinations with their fractional parts, the compounds of various oxides would be so multifarious that all traces of chymical proportion would disappear, or be only occasional, whereas it is found to be perpetual and certain.

17. Knowing the weight of an atom of oxygen and of an atom of hydrogen, we have it in our power to determine the weight of an atom of the other substances which unite with oxygen, or with hydrogen, or with both. One hundred parts of sulphur unite with two well known proportions of oxygen, the first consisting of 100 oxygen, the second of 150 oxygen, both in weight. Here the proportions of oxygen being to each other as 1 : 1½, or as 2 : 3, it was reasonable to suppose that the first proportion represented

2 atoms of oxygen, and the second of 3 atoms, and that there was another compound consisting of 1 sulphur with 1 oxygen. Such a compound, predicted by the theory, has been recently discovered, though not obtained in a separate state as yet. Hence it follows, that the weight of sulphur which enters into these combinations represents the proportional weight of an atom of that substance. Then the combinations of oxygen and sulphur will stand thus :

100 sulphur + 50 oxygen hyposulphurous acid.

100 sulphur + 100 oxygen sulphurous acid.

100 sulphur + 150 oxygen sulphuric acid.

And if 100 represent an atom of sulphur, it is double the weight of an atom of oxygen ; accordingly, the weight of an atom of sulphur is represented by 16 in reference to hydrogen, or by 2 when oxygen is taken as 1.

18. The combination of sulphur with hydrogen leads to the same conclusions. Hydrogen gas, when it unites with sulphur, does not alter its volume, but merely its specific gravity ; consequently the difference of specific gravity between hydrogen and sulphuretted hydrogen gas will shew the weight of sulphur in the latter. The weight of hydrogen and sulphuretted hydrogen may be obtained by comparing each with the common standard, atmospheric air.



| <i>a.</i> | <i>b.</i> | <i>c.</i> | <i>d.</i> | <i>e.</i> | <i>f.</i> | <i>g.</i> | <i>h.</i> |
|-----------|-----------|-----------|-----------|-----------|-----------|-----------|-----------|
| 1000      | : 0694    | :: 30·5   | : 2·116   | 1000      | : 1·180   | :: 30·5   | : 35·990  |

For as 1000 : 1·180 :: 30·5 : 35·9900, from which subtract 2·1160 weight of pure hydrogen, there remains 33·874 weight of sulphur.

Sulphuretted hydrogen therefore is composed of

|          |        |       |    |
|----------|--------|-------|----|
| Hydrogen | 2·116  | . . . | 1  |
| Sulphur  | 33·874 | . . . | 16 |

This shews that if sulphuretted hydrogen gas be composed of an atom of sulphur united to an atom of hydrogen, the weight of an atom of sulphur will be represented by 16, leaving out fractional parts on both sides, for in chymical experiments, absolute precision, or the precision of calculation, is impossible.

The weight of the atom of sulphur is found to be the same by both processes, and our arriving at it, by different methods, strongly corroborates the justness of the conclusion. Such coincidences could not exist unless the inference were well founded.

19. The union of atom to atom is the most energetic because in this, which is called a binary combination, each atom is retained with the whole force

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*a.* sp. gr. of common air.  
*b.* sp. gr. of hydrogen gas.  
*c.* weight of 100 cubic inches air.  
*d.* weight of 100 cub. inch. hydrogen.

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*e.* common air.  
*f.* sp. gr. sulphuretted hydrogen.  
*g.* weight of 100 cub. inch. air.  
*h.* weight of 100 cubic inch. sulphuretted hydrogen.

of the other, the union of  $1\ a + 1\ b$  is the strongest ; if we have  $1\ a + 2\ b$ , then  $2\ b$  will be retained with only half the force of one, and  $3\ b$  with only one third of that force. But in such combinations  $a$  will be retained with the force of  $2\ b$  in the second, and of  $3\ b$  in the third ; accordingly it is very difficult to separate  $a$  or unite it with a third body, whereas it is usually very easy to separate a portion of  $b$  and bring it into a new combination. In such cases the result of experiment coincides exactly with the deductions of the theory.

20. Where a compound cannot be decomposed without a total separation of its constituents, the combination is that of atom to atom ; such is water, which totally decomposes into oxygen and hydrogen, without producing any intermediate substance, partially consisting of the same constituents. It is different with the carbonate and bicarbonate of potash, the second of which contains twice as much carbonic acid as the first. The second loses half its carbonic acid in a moderate heat, whereas the first half is retained even in a red one. The carbonate consists of one atom base and one atom acid, but the bicarbonate of one atom base and two atoms acid. The union of one atom base and one atom acid is energetic, but that of one atom base and two atoms acid is easily broken.

21. When a body has the property of uniting

with various doses of oxygen, we are best enabled to determine the number of atoms which constitute the compounds. Thus manganese unites with 4 doses of oxygen, and if the manganese be represented by 100, the oxygen of each respective oxide is found to be 14, 28, 42, 56. These numbers are in arithmetical progression, having the common difference 14, and are to each other as 1, 2, 3, 4. Hence, the first oxide is composed of one atom manganese and 1 atom oxygen; the second of 1 manganese + 2 oxygen; the third, of 1 manganese + 3 oxygen; and the fourth, of 1 manganese and 4 oxygen. It is observable that the 4th proportion of oxygen is very easily separated, the second and third are less and less so, and the separation of the first, or the total decomposition of the oxide, is extremely difficult.

In like manner as mercury unites with two doses of oxygen and forms 2 oxides, the 1st composed of 100 mercury and 4 oxygen, and the 2nd of 100 mercury and 8 oxygen; the 1st must be a compound of 1 atom mercury + 1 atom oxygen, and the 2nd of 1 atom mercury + 2 oxygen.

There are 2 oxides of iron, the 1st composed of 100 iron and 28 oxygen, the 2nd of 100 iron and 42 oxygen. Now, as  $28 : 42 :: 2 : 3$  it follows that the 1st is composed of 100 iron and 2 atoms oxygen, and the 2nd of 100 iron and 3 atoms oxygen; and we may infer from analogy that there is a lower oxide consisting of 100 iron and 1 atom oxygen.

22. When once we know the gross number of atoms and the amount of each kind in a compound, their proportional weight is easily determined. Thus, if black oxide of mercury be composed of one atom mercury and one atom oxygen, and that 100 mercury combine with 4 oxygen, which experiment proves it does ; then the weight of an atom of mercury is to the weight of an atom of oxygen as 25 to 1 ; and the weight of an atom of black oxide will be represented by  $25 + 1 = 26$ .

23. If water be composed of 1 atom oxygen and 1 atom hydrogen, and if the weight of the oxygen in water is to that of the hydrogen in water, as 8 : 1, then it follows that an atom of oxygen is 8 times as heavy as an atom of hydrogen.

24. Such is the method of determining the weight of an atom of the different substances best known to us by accurate experiment. It enables us to calculate the proportions of the constituents of all compound bodies. It is a standard with which to compare our experiments and try their accuracy. Those that have been conducted with the greatest care and by the ablest experimenters, approach the closest to the conclusions of the theory. The moment it is unequivocally entitled to confidence, it becomes of the greatest assistance to the practical chymist ; for, by determining one or two constituents of a compound, others will be had from calculation with as



much certainty as we can get the inaccessible side of a triangle from 2 angles and one other side.

25. The proportions in which the elementary atoms unite are very limited; almost the whole of them have been examined without finding an exception to the law of their combination. Elementary atoms when they combine form compound molecules of the 1st order; when these unite they form compound molecules of the 2nd order. The combinations of the latter are greatly diversified, varying in their elements as to the number of compound atoms which they contain. Berzelius examined a vast number of these substances, and as they are for the most part composed of oxides he paid particular attention to the oxygen they contain.

From the numerous analytical researches of this eminent philosopher, aided by those of Gay Lussac, and several other distinguished chymists, certain canons have been deduced which are strictly conformable to the atomic theory, and render its applications exceedingly beneficial to the operative chymist.

26. When gaseous bodies combine they always unite in determinate proportions; and if we represent the bulk of the gas that enters into the compound in the smallest quantity in bulk by 1, then the bulk of the other constituent is either 1, 2, or 3, &c. Thus, muriate of ammonia is composed of 1 muriatic gas + 1 ammoniacal gas; carbonate of am-

monia of 1 carbonic acid gas + 1 ammoniacal gas ; nitrous gas of 1 nitrogen + 1 oxygen ; water of 1 oxygen + 2 hydrogen ; nitrous acid of 1 nitrogen + 2 oxygen ; sulphuric acid of 1 oxygen + 2 sulphurous acid gas, because the sulphurous acid gas consists of 1 sulphur + 2 oxygen, carbonic acid of 1 oxygen + 2 gaseous oxide of carbon, for the latter is formed of 1 carbon + 1 oxygen ; ammonia of 1 nitrogen + 3 hydrogen. This canon has been established by Gay Lusac in a satisfactory manner.

The same result is observable in all the compounds of inorganic matter, one of the constituents of which is uniformly in the state of a single atom. This law greatly simplifies the doctrine of atomic combinations, as far as inorganic bodies are concerned, and reduces the whole to a state of elementary facility.

27. The quantity of acid requisite to saturate the different metals is directly as the quantity of oxygen which these metals require to convert them into oxides. Thus, 100 parts of mercury require 4.16 parts of oxygen, and 100 parts of silver require 7.9 parts of oxygen, to convert them into oxides. Therefore, the quantity of acid necessary to saturate 100 parts of mercury is to the quantity necessary to saturate 100 parts of silver as the number 4.16 to 7.9. This law was first pointed out by Gay Lusac. Dr. Thomson expresses it in the following manner.

the better to adapt it to the purposes of the chymist. "When different metallic oxides saturate the same weight of acid, each contains exactly the same weight of oxygen.

According to Berzelius, in order to saturate 100 parts muriatic acid, any metal whatever must be combined with 42 parts of oxygen. To saturate 100 parts of sulphuric acid, any metal whatever must be combined with 20 parts of oxygen.

This law necessarily implies that when an acid unites to a base, the oxygen in the acid is always a multiple of the oxygen in the base by a whole number; and generally by the number denoting the atoms of oxygen in the acid. Thus, sulphuric acid is composed of 1 atom sulphur = 16 and 3 atoms oxygen = 24, and 100 parts of sulphuric acid containing 60 oxygen, ( $24 : 16 :: 60 : 40$ ) will combine with and saturate a quantity of base which contains 20 oxygen. Now, 20, the oxygen in the base, multiplied by 3, the number of atoms in sulphuric acid, makes 60, the quantity of oxygen in 100 parts of sulphuric acid.

28. When sulphur combines with a metal, the proportion remains unchanged, though the sulphur be converted into an acid, and the metal into an oxide. Thus, the proportion of metal and sulphur in sulphate of copper is the same as in sulphuret of copper. For the proto sulphuret of copper is composed of 1 atom sulphur + 1 atom copper; and the

sulphate of the protoxide of copper is composed of  
1 atom sulphur + 3 atoms oxygen (acid.)

1 atom copper + 1 atom oxygen (protoxide or base.)  
in which the sulphur and copper do not vary.

This law which is of great importance in practical chymistry, and very much facilitates the analysis of the metalline salts, was first pointed out by Berzelius.

29. The oxygen in a metallic protoxide is equal to half the sulphur in the sulphuret of the same metal, supposing the weight of the metal in both cases to be the same. This canon was first specified by Berzelius. It depends on the fact that an atom of sulphur is twice the weight of an atom of oxygen; and it is limited to those cases where the protoxide is a compound of 1 atom of metal and 1 atom of oxygen; and the sulphuret of 1 atom of metal and 1 atom of sulphur. This canon enables us to determine the constitution of the sulphurets by means of the oxides, and vice versa.

30. In combinations of two bodies, each containing a quantity of oxygen, the weight of oxygen in each body is either equal, or one contains twice, thrice, four times, &c. as far as eight times the quantity of oxygen in the other. This law has been laid down by Berzelius, and indicates a most important regularity in the relative weights of the atoms of bodies.



31. Water is capable of combining both with acids and bases; when it unites with an acid it acts the part of a base, and contains the same quantity of oxygen that the base would contain. Therefore, the least quantity of water that can combine with sulphuric acid is 22.5 water, to 77.5 acid; for  $8 : 9 :: 20 : 22.5$ . That is to say, 8, the atom of oxygen is to 9, the integrant particle of water, as 20 oxygen is to 22.5 water; and the water forming a base, in 100 sulphuric acid, it must contain 20 oxygen. This acid has therefore no more water than is barely sufficient for its formation, hence it is the strongest possible. Such compounds are called hydrates. This canon has also been laid down by Berzelius.

32. In combinations composed of more than two bodies containing oxygen, the oxygen of that constituent which contains the least of it is a common divisor of all the portions of oxygen found in the other bodies. This law, likewise laid down by Berzelius, depends on the fact that oxygen always unites by atoms, whence it follows that any quantity of oxygen will always be divisible by one atom of oxygen. Dr. Thomson observes that if we were accurately acquainted with the constitution of the earths, this law would be of great use to the mineralogist. It would enable him to distinguish between chymical combinations and mechanical mixtures.

33. When two combustible bases unite, they always combine in such a proportion that when oxi-

dized, either the quantity of oxygen uniting with each will be the same, or the oxygen in the one will be twice, thrice, &c., that in the other. This is another law laid down by Berzelius, and depends on this fact, that the two bodies must unite, atom to atom, or a certain number of the atoms of the one must combine with one atom of the other. Dr. Thomson applies this law to determine which of the metallic alloys are chymical combinations, and which are mechanical mixtures. There can be no doubt that copper and zinc combine chymically. Now, the weights of the atoms of these metals are,

|        |   |   |       |
|--------|---|---|-------|
| Copper | - | - | 8.000 |
| Zinc   | - | - | 4.315 |

Therefore, if they unite atom to atom, brass ought to be a compound of 100 copper and 53.93 zinc,  $8 : 4.315 :: 100 : 53.93$ . Actual analysis shews this to be very nearly the proportion of the ingredients.

34. Those are the canons of Berzelius, but founded on analysis. (2 Thom. Annal. p. 40.) By means of them he determines the proportion of oxygen in bodies, and the number of atoms of which they are composed. These laws give a facility and elegance to our chymical investigations scarcely to be expected; and they must be admitted until some exception to them be discovered.

It is a circumstance much in favor of the atomic theory, that it assigns a mechanical and very satisfactory cause, why elementary atoms unite only in

proportions which are multiples of each other. The compound molecules which contain oxygen, combine likewise in a multiplex ratio, if we attend only to the oxygen they contain. This must be owing, in all probability, to a cause similar to that which occasions the like proportions between elementary atoms themselves.

The proportion of oxygen, in the oxides that unite, is a problem highly important to be verified. The investigation has accordingly occupied and still continues to occupy the attention of the ablest chymists with a result the most satisfactory.

Indeed but for the law which shews that the oxygen in an acid is always a multiple of the oxygen in the base by a whole number, no combination composed of several oxides could be calculated, nor any analysis verified in a decisive manner for the theory.

35. The employment of numbers facilitates the expression of chymical proportions, and, by determining the weight of the elementary atoms, figures exhibit the numeric result of an analysis in a manner at once simple and easily remembered. But, in order to draw up a table of the relative weights of the atoms of bodies, some one must be selected for comparison, whose atom shall be denoted by unity.

There are only two elementary bodies possessed of the requisite qualities to serve as our unit. These are oxygen and hydrogen. Mr. Dalton has made

choice of hydrogen, because it is the lightest of all known bodies. Sir H. Davy embraced it from him, but changed its value; and Mr. Brande, in his *Manual of Chymistry*, lately published, has likewise adopted the unit and computation of Dalton, but designates the relation of elementary parts by the term *proportionals*. This choice was not the happiest, for hydrogen has disadvantages from which oxygen is free. The weight of an atom of hydrogen is so small, that if we employ it as our unit, the number representing an atom of some of the metals becomes inconveniently great.

Besides, hydrogen enters much less frequently into compounds than oxygen, and, of course, the unit of comparison, when applied to hydrogen, does not nearly so much facilitate calculation as when it is applied to oxygen. Add, that oxygen constitutes among elementary bodies a particular class; and is, as it were, the center round which chymistry turns. It exists in the greater number of inorganic bodies, and, without exception, in all the products of organic nature. For these reasons Berzelius preferred this unit, as most convenient and most agreeable to the scientific views of chymistry. He represents it by 100. (2 Th. An. 451.)

Dr. Wollaston and professor Thomson, for similar reasons, have both adopted oxygen as the most convenient unit; nor can there be any hesitation in



embracing their decision. Oxygen is, in fact, the substance by means of which the weight of the atoms of all other bodies is determined; hence, the great advantage, for the practical chemist, attending a convenient number for that body.

Much confusion has arisen in this department of the science, not only from the diversity of the unit, but also from the circumstance of different chymists having taken the same unit of different values. Berzelius, as already observed, takes it at 100; Wollaston at 10; and Thomson at 1. There is, indeed, no real difference between the three last, for any one of them may be converted into the other without an alteration of figures, by simply changing the place of the decimal point. Yet, it is much to be desired that the same numbers were steadily employed by all persons, as they would soon be recollected by chymists, who would thus have a ready recollection of every compound without the trouble of referring to a book.

36. Having observed in my lectures to the students of this college, that the doctrine of atoms was sooner made familiar to the imagination, when the numbers representing their proportional weights are reduced to their lowest terms, and being also more easily remembered when thus expressed, I have preferred the unit adopted by Dr. Thomson.

37. Gay Lussac and Thenard, to whom, next to

Berzelius, the corpuscular theory of chymistry is most largely indebted, have not failed, with many valuable improvements, to introduce a further perplexity, by determining chymical proportions in volumes and not in atoms. Their method is indeed founded on a fact discovered by Gay Lussac, namely, that bodies when in a state of gas unite either in equal volumes, or 1 volume of one combines with 2, 3, &c. volumes of the other; a fact which has been verified by several other distinguished chymists. Berzelius, also, prefers the computation in volumes; and, though, in the meaning of those very eminent chymists, volumes are but another name for atoms, yet it injures the unity and simplicity of the doctrine to represent essential principles in such diversified forms and expressions. It is true that in the present state of our knowledge, the theory of volumes has the advantage of being founded on a well constituted fact, and it admits of our taking a demi-volume in calculation; while, in the theory of atoms, a demi-atom is an absurdity. But then it is a very forced and unnatural assumption to represent all bodies in a state of gas, even those which were never known to assume that form, or which can be supposed ever to exist in it, in order to determine the proportional weights of their constituent parts. Hence, as there is in reality no difference intended by the theory of volumes, but that

of representing bodies in a gaseous, which the theory of atoms represents in a solid form, I prefer the theory of atoms as subject, on the whole, to fewer difficulties.

38. Oxygen, - - - - - 1

39. It was proved in sections, 7, 8, 9, that hydrogen is but 1·8 part as heavy as oxygen. Hence, by dividing 8 into 1 we obtain the fractional proportion for hydrogen 0·125.

40. *Carbon.* When carbon is burned in oxygen, the volume of the gas is not altered, but it is converted into carbonic acid gas. Hence, if from the weight of 100 cubic inches of carbonic acid gas = 46·313 grains, we subtract the weight of 100 cubic inches of oxygen gas = 33·688, the difference 12·641 grs. gives the weight of carbon in 100 cubic inches of carbonic acid gas. It shews that this gas is composed, per cent, of 27·29 parts carbon and 72·71 oxygen, for 46·313 carbonic acid is to 12·641, its proportion of carbon, as 100 carbonic acid is to 27·29, its proportion of carbon; and by subtracting the carbon, the remainder 72·71 gives the oxygen.

There is also another combination of oxygen and carbon necessary to be considered before we can determine the proportional number for carbon. It is carbonous oxide, a gas that may be formed by partially decomposing carbonic acid.

When a well dried carbonate, such as carbonate

of barytes, or lime, is distilled with dry iron filings, the iron attracts a part of the oxygen of the carbonic acid of the carbonate, and the remainder minus, the portion of oxygen thus taken from it, becomes carbonous oxide ; a gas containing less oxygen, therefore, than carbonic gas. But if to the same carbonous oxide half its volume of pure oxygen gas be now added, and the electric spark is passed, it becomes carbonic acid gas again. In these two experiments the carbon has not been affected ; it is the same in both, the oxygen only has been partially taken off in the first, it is restored in the second. Now, since there is the same weight of carbon = 12·641 grains in 100 cubic inches of both, deducting this from the weight of both, we get the weight of oxygen in each.

Thus \* 46·313 — 12·641 = 33·688 the oxygen in 100 carb. acid ; and † 29·158 — 12·641 = 16·517 the oxygen in 100 carbonous oxide. But as 16·517 is very little more than half 33·688, it is proved that carbonous oxide contains but half the oxygen of carbonic gas, and therefore that there are twice as many atoms in the latter as in the former—and that if the first be a binary compound consisting of an atom carbon and an atom oxygen, the second is a ternary compound of an atom carbon and two atoms oxygen.

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\* weight of 100 cubic inches carbonic gas.

† weight of 100 cubic inches carbonous oxide gas.



To find the proportional weight of the atom of carbon, take the oxide of carbon which is binary, and as 16·517 weight of oxygen is to 12·641 weight of carbon, so is 1, weight of an atom of oxygen to ·765 weight of the atom of carbon.

The weights 46·313 and 29·158 may be readily deduced from the sp. gr. of those gases.

The sp. gr. of carbonic gas = 1·519

That of carbonic oxide = 0·956 now

$$1 : 30·5 :: 1·519 : 46·313$$

$$1 : 30·5 :: 0·956 : 29·158$$

*i. e.* 1, the sp. gr. of atmospheric air, is to 30·5, weight of 100 cubic inches of atmospheric air, as 1·519 sp. gr. : of carbonic gas, is to 46·313 weight of 100 cubic inches of the same gas.

41. *Nitrogen.* There are five compounds of nitrogen and oxygen gas, which it is necessary to examine, the better to determine the weight of the atom of nitrogen.

1 Protoxide of nitrogen or nitrous oxide gas. It is composed of 2 volumes of nitrogen and

1 volume of oxygen.

Now 1 volume, say 100 cubic inches, of oxygen weighs 33·888 grains, and 2 volumes, or 200 cubic inches of nitrogen, weigh  $29·652 \times 2 = 59·304$  grains, therefore the protoxide weighs the sum of their weights,  $33·888 + 59·304 = 93·272$  grains. To find the weight of each constituent in 100 grains,

as the compound 93.272 is to 33.888, its proportion of oxygen, so is the compound 100 grs. to 36.3 grs., the oxygen in 100 of the protoxide. Consequently  $100 - 36.3 = 63.7$ , the nitrogen in 100 protoxide.

|            |   |   |   |                |
|------------|---|---|---|----------------|
| Protoxide, | - | - | - | 63.7 nitrogen, |
|            |   |   |   | 36.3 oxygen,   |
|            |   |   |   | <hr/>          |
|            |   |   |   | 100.0          |

2d. Deutoxide, or nitrous gas, composed of  
 1 volume nitrogen and  
 1 volume oxygen.

The volumes of nitrogen and oxygen weigh as above  $29.652 + 33.888 = 63.540$ , and to find the weight of each constituent in 100 of nitrous gas  $63.540 : 33.888 :: 100 : 53.33$  oxygen, and  $100 - 53.33 = 46.67$  nitrogen.

Now let the base, or nitrogen be the same, = 63.7 in all the combinations of nitrogen and oxygen, and then as 46.67 nitrogen : 53.33 oxygen :: 63.7 nitrogen in the protoxide : 72.7 oxygen in the deutoxide or nitrous gas. It is evident from this that, the oxygen in the nitrous gas is double that in the protoxide, for  $72.7 = 36.3 \times 2$ .

3d. *Hyponitrous Acid*. This acid discovered by Thenard, and by him called pernitrous acid, is composed of 175 nitrogen and 300 oxygen by weight. Then to find the oxygen, the nitrogen being the same as that of the protoxide 63.7.

as  $175 : 300 :: 63.7 : 109.2$ . This shews that the oxygen in the hyponitrous acid is three times that of the oxygen in the protoxide for  $36.3 \times 3 = 109.9$

4th. *Nitrous acid*. This acid is composed of

1 volume nitrogen and

2 volumes oxygen.

The volume nitrogen =  $29.652$  as above, and 2 vol. oxygen or  $33.888 \times 2 = 67.776$ . Therefore, the nitrous acid here weighs  $29.652 + 67.776 = 97.428$ . But to find the weight of each constituent in 100, we have this proportion  $97.428 : 67.776 :: 100 : 69.56$ , oxygen in 100 nitrous acid, and  $100 - 69.56 = 30.44$  nitrogen in 100 ditto. Now in order to find the ratio in which the oxygen increases in these combinations, we have given the base  $63.7$  and we get the oxygen in nitrous acid belonging to that base, by the following proportion:—

$30.44$  nitrogen :  $69.56$  ox. ::  $63.7$  :  $145$  ox : in nitrous acid. The oxygen in nitrous acid is therefore four times as much as in the protoxide for  $36.3 \times 4 = 145.2$ .

5th. *Nitric acid*. This acid is composed of

1 volume nitrogen and

2.5 volumes oxygen,

or by weight of  $35.12$  nitrogen and

100 oxygen.

Then to find the oxygen when the nitrogen is  $63.7$  we have the proportion as  $35.12 : 100 :: 63.7 : 181.3$ ,

oxygen in nitric acid, to 63·7 nitrogen. The oxygen in this combination is five times that in the protoxide, for  $36\cdot3 \times 5 = 181\cdot5$

From all these combinations it may reasonably be assumed that the oxygen enters with the nitrogen into a regular arithmetical increase from the protoxide upwards, thus,

protox : deutox : hyponit : nitrous acid : nitr. acid.

36·3 ; 72·7 ; 109·9 ; 145·23 ; 151·3.

These numbers are to each other as 1, 2, 3, 4, 5, very nearly, hence we may consider the protoxide as the lowest combination, or as a binary in which 1 atom of oxygen unites with 1 atom of nitrogen, and from it the proportional weight of an atom of nitrogen may be obtained, as 36·3 oxygen : 63·7 nitrogen :: 1 atom ox. : 1·75 atom of nitrogen.

42. *Phosphorus*. According to the experiments of Lavoisier and Davy, 100 parts of phosphorus unite with and condense 154 parts oxygen, and form phosphoric acid ; which consists therefore in a hundred parts, of 39·38 phosphorus and 60·62 oxygen ; but 39·38 : 60·62 :: 1 : 1·54. or else 100 : 154 :: 1 : 1·54. The atom of phosphorus is represented therefore by the proportional 1·54, or 1·5. Another but a more complicated method of arriving at the same result is that of examining the neutral salts which phosphoric acid forms with the different bases. We find then that phosphorus forms with oxygen three acids,



|                      | phos. | oxygen. |
|----------------------|-------|---------|
| Hypophosphorous acid | 1·5   | + 1     |
| Phosphorous acid -   | 1·5   | + 2     |
| Phosphoric acid - -  | 1·5   | + 3     |

43. *Sulphur.* There are two well known combinations of oxygen and sulphur, viz. the sulphuric and the sulphurous acids. It has been shewn (sect. 17,) that the latter holds two-thirds the quantity of oxygen contained in the former. It has been also shewn that the sulphuric acid contains 100 sulphur + 150 oxygen (ibid.) Hence, sulphurous acid must contain two thirds of 150 = 100 oxygen. Now, if we suppose oxygen to unite with sulphur according to a given arithmetical progression we will obtain its lowest combination by constantly taking the common difference from the last lowest term until the difference is too great to be deducted, or until nothing remains. Thus, two of the terms found are 150 and 100, their difference is 50; therefore  $100 - 50 = 50$  will express the next term lower than 100. It is also the lowest for 50, the term last found — 50 common difference = 0; therefore, 50 is the quantity of oxygen uniting with sulphur when the union is the lowest that can be. It is therefore a binary in which 1 atom of oxygen unites with 1 atom of sulphur, and it will be expressed 100 sulphur + 50 oxygen, from which we obtain the proportional weight of an atom of sul-

phur, as 50 oxygen : 100 sulphur :: 1 weight of an atom of oxygen : 2 weight of an atom of sulphur. For if there be the same number of atoms in 100 by weight of sulphur as in 50 by weight of oxygen, it is evident that the single atoms themselves must bear to each other the same proportion as their multiples do.

44. *Sodium.* When 100 grs. sodium are thrown into water there is a decomposition of the latter and 198.30 cubic inches of hydrogen gas are set free; the temperature being = 60, and the barometric pressure = 30 inches. The hydrogen, as a constituent of water, requires half its volume of oxygen, that is  $198.30 \div 2 = 99.15$  cub : inches, which is the quantity of oxygen that unites with the sodium to form soda. But 99.15 cubic inches of oxygen gas weigh 33.6, therefore soda is composed of 100 sodium + 33.6 oxygen; or taking the mean of several experiments 33.3.

The peroxide of sodium is composed of 100 sodium + 50 oxygen by weight. Now the oxygen in soda (33.3) is to the oxygen in the peroxide of sodium (50) as 2 is to 3 nearly; and if 2 and 3 are the lowest proportional terms to which 33.3 and 50 can be reduced, the 2 must represent 2 atoms, and the 3 three atoms. The lower numbers than 2 and 3, viz. 1 and 1.5 must be rejected, for there can be no fractional part of an indivisible atom; 2 and 3 are therefore the lowest proportionals. This

gives soda as a deutoxide, and the peroxide of sodium as a tritrooxide. From either of these we may deduce the proportional weight of an atom of sodium. Thus, for the deutoxide, or when one atom of sodium unites with two of oxygen.

As  $33\cdot3$  oxygen : 100 sodium :: 2 atoms weight of oxygen :  $6\cdot006$  weight of an atom of sodium. Hence, 1 atom of sodium =  $6\cdot006$ .

Whatever be the state of oxidation of soda, the peroxide of sodium must be the next greater, for there can be no intermediate one between 2 and 3 atoms.

45. *Potassium.* It follows from a comparison of the experiments of Davy, Gay Lusac, Thenard, and Berzelius, that pure potash is a binary compound of 100 potassium and 20 oxygen by weight ; and as in this compound, being the lowest, 1 atom of potassium combines with one atom of oxygen, these respective atoms will be in the same proportion, i. e.

oxygen, potas.      atom ox.

$20 : 100 :: 1 : 4$  weight of the atom potassium.

Again, Gay Lusac and Thenard have shewn that the peroxide of potassium is composed of 100 potassium and 60 oxygen ; or 3 times the quantity in the protoxide ; therefore oxygen combines with potassium in the proportion of 1 to 3, shewing the peroxide as a compound of 1 potassium + 3 oxygen.

46. *Barium.* The base of baryta may be deter-

mined from the combination of baryta with sulphuric and carbonic acids.

Sulphate of baryta is composed of acid  $100 + 194$  base, and the carbonate of acid  $100 + 354.54$  base. Now, according to a canon of Berzelius deduced by him from numberless experiments, whenever a base and an acid combine, the oxygen in the acid bears a fixed relation to the oxygen in the base. One hundred parts by weight of sulphuric acid will saturate a quantity of base, containing 20 parts oxygen; a 100 parts carbonic acid will saturate a quantity of base containing  $36.26$  parts oxygen. Hence, 194 parts baryta, which combine with 100 sulphuric acid, contain 20 oxygen; and  $354.54$  baryta, which combine with 100 carbonic acid, contain  $36.267$  parts oxygen. To obtain the proportion of oxygen in 100 of baryta from these data we say, as 194 baryta : 20 oxygen :: 100 baryta : 10.309 oxygen. And as  $354.54$  baryta :  $36.267$  oxygen :: 100 baryta : 10.2 oxygen. The mean of these (10.269) is the oxygen in 100 of baryta; and if the oxygen be 10.269, the barium is 89.731. Reducing these numbers to their lowest terms, if the atom of oxygen be 1 the proportional weight of the atom of barium will be 8.73.

47. *Calcium*, as far as yet known, combines with only one proportion of oxygen and forms the important oxide lime. It is from the sulphate and carbo-



nate that we can best arrive at the composition of lime, and this method admits of considerable accuracy.

Sulphate of lime has been analyzed with great care, and is a compound of sulphuric acid 100.....5

lime . . . . . 72·41....3·620

That is, 100 sulphuric acid are to 72·41 lime as 5, the integrant particle of sulphuric acid, is to 3·620, the integrant particle of lime.

Carbonate of lime has been likewise analyzed with great care, and is composed of

|               |   |      |   |       |
|---------------|---|------|---|-------|
| carbonic acid | - | 43·2 | - | 2·75, |
| lime          | - | 56·8 | - | 3·61. |

Thus, the equivalent number for lime, by both experiments, is the same ; and as calcium combines with only one proportion of oxygen, we must suppose lime a compound of 1 atom calcium + 1 atom oxygen.

|         |      |   |       |
|---------|------|---|-------|
| calcium | 2·62 | - | 100   |
| oxygen  | 1·00 | - | 28·67 |

48. *Strontium.* The proportional weight of an atom of strontium may be obtained after the same manner as that of Barium. Sulphate of strontium is composed, according to the experiments of Stromeyer, of strontian, (viz. oxide of strontium) 132·55 sulphuric acid - - - 100

and carbonate of strontian, by the experiments of Dr. Thomson of strontian - 234·44

carbonic acid - 100

Now, since sulphate and carbonate of strontian are composed of integrant particles of oxide of strontium and sulphuric acid in binary combination; we may find the weight of an integrant particle of strontian by knowing that of either of the acids. The integrant particle of sulphuric acid is represented by 5; namely, 1 atom sulphur = 2, and 3 atoms oxygen = 3; and the integrant particle of carbonic acid by 2.76 viz. 76 carbon and 2 oxygen. To deduce the weight from the sulphate we use the proportion as 100 sulph. acid : 132.55 strontian :: 5 weight of an integrant particle of sulphuric acid : : 6.62 weight of an integrant particle of strontian, 100 : 132 :: 5 : 6.62.

To deduce it from the carbonate, as 100 carb. acid : 234.44 strontian :: 2.76 : 6.47. The mean of these two 6.62 and 6.47 gives 6.5 without any sensible error for the weight of an integrant particle of strontian.

It is known that 100 parts of sulphuric acid will combine with a base, having 20 parts oxygen; hence, 132.55 parts of strontian have 20 parts of oxygen, or 100 have 15.08. It is likewise known that 100 parts carbonic acid require a quantity of base having 36.267 oxygen; hence, 234.44 parts strontian have 36.267 oxygen, or 100 have 15.46, nearly the same as that from the sulphate. The mean of both

results is 15·27, the parts of oxygen in 100 of strontian, which therefore consists in 100 parts of

|           |   |   |   |       |
|-----------|---|---|---|-------|
| oxygen    | - | - | - | 15·27 |
| strontium | - | - | - | 84·70 |

---

100·

Now, one integrant particle of strontian = 6·5 divided in the proportion of 100 parts will give the weight of an atom of strontium, which, as far as we can view it, must consist of 1 atom of strontium + 1 atom of oxygen. Therefore, 100 strontian : 15·27 oxygen, :: 6·5 strontian : 0·99275 oxygen in one integrant part of strontian. A result so near 1 the weight of an atom of oxygen, that it may be taken as such. Then  $6·5 - 1 = 5·5$  weight of an atom of strontium.

49. *Magnesium.* Magnesium may be determined like barium and strontium. The sulphate of magnesia, according to Berzelius, is composed of

|                |   |   |   |       |
|----------------|---|---|---|-------|
| sulphuric acid | - | - | - | 100   |
| magnesia       | - | - | - | 50·06 |

and as there is but one combination of sulphuric acid and magnesia known, we must consider it a binary, formed by the union of 1 integrant particle of sulphuric acid, joined to 1 integrant particle of magnesia. The integrant particle of sulphuric acid is 5, therefore, as  $100 : 50·06 :: 5 : 2·51$ , the integrant particle of magnesia.

Further, 100 parts of sulphuric acid require a base containing 20 parts oxygen; hence, 50.06 parts of magnesia contain 20 oxygen, or 100 contain 40. Now, to find the proportional part of oxygen in 2.51. integrant particle of magnesia, the same as in 100, there is the proportion  $100 : 40 :: 2.51 : 1$ .

magnesium = 1.5 - - - atom of magnesium.

oxygen - 1 - - - ditto ' oxygen.

50. *Yttrium*. According to the analysis of Berzelius, the sulphate of yttria is composed of equal weights of acid and base; hence, the weight of an integrant particle of yttria is the same as that of sulphuric acid = 5.

Since we know but one combination of yttrium and oxygen, and that oxygen is 1, yttrium must be 4.

Moreover, since 100 parts sulphuric acid require as much base as contains 20 parts oxygen, finding the oxygen of one integrant particle in the same proportion as that of 50, we arrive at the above result, as well by this useful canon of Berzelius, as by his analysis, since  $50 : 10 :: 5 : 1$ . The integrant particle of yttria is 5, and deducting 1 oxygen, the atom yttrium = 4.

51. *Glucinum*. The sulphate of glucina, by the experiments of Berzelius is composed of

|                |   |      |
|----------------|---|------|
| sulphuric acid | - | 100  |
| glucina        | - | 64.1 |



Considering the sulphate as formed by the union of particle to particle, the weight of an integrant particle of glucina is determined by that of sulphuric acid as  $100 : 64.1 :: 5$  weight of the integrant particle of sulphuric acid :  $3.205$ , integrant particle of glucina. And as  $64.1$  parts glucina saturate  $100$  parts sulphuric acid, they contain  $20$  parts oxygen, and we obtain the oxygen in an integrant particle of glucina by the proportion as  $64.1 : 20 :: 3.205 : 1$ ; consequently  $3.205 - 1 = 2.205$  weight of an atom of glucinum.

52. *Aluminum.* The weight of the atom of aluminum is also determined from the experiments of Berzelius by means of the sulphate. It consists of

acid            -        -        -        100

alumina            -        -        42.722 hence

as  $100 : 42.722 :: 5 : 2.115$ ; and the oxygen in  $2.115$  is in the same proportion as in  $42.722$ , that is as  $42.722 : 20 :: 2.115 : 1$  and  $2.115 - 1$  oxygen =  $1.115$  weight of an atom of aluminum.

53. *Zirconium.* As no very accurate analysis of the union of acids and zirconia have been made, the number for an atom of zirconium, deduced from the analyses Klaproth and Vanquelin, can only be considered as an approximation. From the analyses of those chymists we are led to consider the weight of a particle of zirconia, as represented by  $5.625$ , and supposing it the lowest union of oxygen and zirconium,

for we know no lower ; the weight of the atom of zirconium is found  $= 4.620$  by deducting 1, the weight of oxygen.

54. *Iron.* The weight of an atom of iron may be obtained from the salts which it forms, by applying to them the canon of Berzelius, that an acid will combine only so far with a base as its oxygen bears a proportion to the oxygen of the acid. In all combinations of sulphuric acid and a base, no matter in what quantity we take one, the oxygen of the acid must be to that of the base as  $60 : 20$ . Different acids have different proportions with regard to their oxygen and that of the base with which they unite. As, for instance the oxygen in carbonic acid is always to that of the base with which it unites as  $72.73$  nearly is to  $36.267$ .

This is a most important law and merits constant attention, from the great variety of cases to which it is applicable. Proceeding by this method, if we take the combination of iron with sulphuric acid, it is composed, according to Berzelius, of

|                   |   |   |     |
|-------------------|---|---|-----|
| Sulphuric acid    | - | - | 100 |
| Protoxide of iron | - | - | 88  |

and since composed of particle to particle, by knowing the weight of the integrant particle of sulphuric acid, we can obtain that of iron ; for as  $100 : 88 :: 5 : 4.4$ , weight of an integrant particle of protoxide of iron :

and subtracting 1, the atom of oxygen, 3.4 will represent the atom of iron.

Or by the canon of Berzelius, as 88 protoxide of iron is to 20 oxygen, so is 4.4, integrant particle of protoxide of iron, to 1; but 1 is the weight of an atom of oxygen, and as the protoxide is composed of an atom of oxygen + an atom of iron,  $4.4 - 1 = 3.4$ , as above.

It may be obtained from other acids with which iron combines by a similar process.

55. *Tin*. There are two well defined oxides of Tin; the 1st composed of 100 tin + 13.6 oxygen, the 2d. of 100 metal + 27.2 oxygen; from which it appears that the oxygen of the first is one-half that of the second, or as 1 : 2. Hence 100 tin + 13.6 is a protoxide composed of atom to atom. We have therefore this proportion as  $13.6 : 100 :: 1 : 7.352$  weight of an atom of tin.

56. *Copper*. There are two oxides of copper determined by very exact experiments, the first composed of 100 metal + 12.5 oxygen, the second of 100 metal + 25 oxygen, now  $12.5 : 25 :: 1 : 2$ . Hence the first is a protoxide of one atom metal + 1 atom oxygen, which gives the weight of the atom of copper thus, as  $12.5 : 100 :: 1 : 8$  weight of the atom of copper.

57. *Bismuth*. There is but one oxide of bismuth. It is formed by the union of 100 metal with 11.267 oxygen. We must deem it a protoxide because we

do not know any lower ; and to determine the weight of the atom of bismuth we say as  $11.267 : 100 :: 1$  atom ox. :  $8.785$  atom of bismuth.

58. *Mercury.* We may in most cases of the metallie oxides determine which is the protoxide by applying the canon of Berzelius, "that the oxigen of the protoxide is one-half the sulphur in the lowest sulphuret of the same quantity of metal." Now the lowest sulphuret of mercury contains, according to Guibault,  $8.2$  sulphur +  $100$  metal. Hence the protoxide of mercury must contain  $8.2 \div 2 = 4.1$  oxigen +  $100$  metal.

Sofstrom, as quoted by Berzelius, found the protoxide composed of  $100$  metal +  $3.99$  oxigen, and the peroxide of  $100$  metal +  $7.99$  oxigen. Hence we may take  $4$  for the oxigen in the protoxide, and  $8$  for that in the peroxide ; and the atom of mercury will be represented by  $25$ , as  $4 : 100 :: 1 : 25$ .

59. *Silver.* According to Vauquelin, a protosulphuret of silver is composed of  $100$  metal +  $14.59$  sulphur. Hence the protoxide of silver must contain  $7.29$  oxigen nearly +  $100$  silver.

There is but one oxide of silver known composed according to Thomson, of  $7.291$  oxigen +  $100$  metal. Hence, by the canon of Berzelius, this must be the protoxide. Therefore, as  $7.29 : 100 :: 1$  (atom ox.) :  $13.71$  weight of an atom of silver.

60. *Gold.* Berzelius obtained two oxides of gold.



the second containing three times the oxygen contained in the first. First oxide 100 gold + 4.005 ox.

The Peroxide 100 do. + 11.982 ox.

Hence as the difference is 3 in this progression, oxygen can not combine with gold according to any other term above unit than the first, which is therefore a binary, composed of one atom of gold + one atom oxygen. We have therefore this proportion to determine the weight of an atom of gold as 4.005 : 100 :: 1 : 24.96.

The peroxide is a quaternary as it consists of 1 atom gold + 3 atoms oxygen.

61. *Platinum*. From the experiments of Mr. Cooper, it follows that 100 parts of platinum combine with 4.423 oxygen, hence the atom of platinum must weigh 22.625.

62. *Palladium*. Berzelius determined the only known oxide of palladium as composed of 100 palladium + 14.209 oxygen. If this be a protoxide the atom of palladium will be 7.03, for 14.209 : 100 :: 1 : 7.03.

But if we suppose the sulphuret of palladium, as found by Vauquelin, to consist of 100 metal + 24 sulphur, and to be a protosulphuret, then the atom of palladium would be represented by 8.333 for  $24 \div 2$  : 100 :: 1 : 8.333.

63. *Rhodium*. There are three oxides of rhodium composed, as determined by different analyses of 1st.

100 metal + 6.71 oxygen; the 2d 100 metal + 13.42 oxygen; the 3d 100 metal + 20.13 oxygen. Now 6.71, 13.42 and 20.13 are to each other as 1, 2, 3, and consequently the first is a protoxide, and 6.71 : 100 :: 1 : 14.9 or nearly 15 weight of the atom of rhodium.

64. *Iridium*. The oxides of iridium have not been determined; but if the sulphuret, composed according to Vauquelin, of 100 metal + 33.3 sulphur, be considered as a protosulphuret, the weight of the atom of iridium will be found as 33.3 : 100 :: 2 (weight of an atom of sulphur) : 6 atom of iridium.

65. *Antimony*. Antimony forms several oxides, the lowest of which, according to Berzelius, is composed of 100 metal + 18.6 oxygen; the next of 100 + 27.9; and a third of 100 + 37.2. Now, these numbers are to each other as 2, 3, 4; hence, the first appears to be a deutoxide, therefore 18.6 : 100 :: 2 (weight of 2 atoms oxygen,) : 10.75 weight of the atom of antimony. But Dr. Thomson makes the atom of antimony 5.625, taken from his analysis of the sulphuret of antimony, which he finds composed of 100 antimony + 35.572 sulphur. Now, 35.572 : 100 :: 2 : 5.625.

66. *Molybdenum*. From the experiments of Bucholtz there seems to be three oxides of this metal. The greatest, molybdic acid, composed of 100 metal + 50 oxygen; the next, molybdous acid, of 100 metal + 33.3 oxygen. The third has not been ana-

lyzed ; but as oxygen combines in an arithmetical progression the difference between 50 and  $33\cdot3 = 16\cdot7$  taken from 33·3 will give the next lowest term to  $33\cdot3 = 16\cdot6$  oxygen.

But independent of this step  $33\cdot3 : 50 :: 2 : 3$  nearly. Hence, the oxide of 100 metal and 33·3 oxygen is a deutoxide, by means of which we may obtain the atom of molybdenum.

As  $33\cdot3 : 100 :: 2$  (weight of 2 atoms oxygen) : 6, weight of the atom of molybdenum.

67. *Tungsten*. It is proved, by experiment of Messrs. D'Elhuyarts, Bucholtz, and Berzelius, that tungstic acid is composed in the proportion of 100 tungsten and 25 oxygen ; and Berzelius has also shewn that brown oxide of tungsten contains very nearly two thirds the quantity of oxygen that exists in tungstic acid, or that it is composed of about

|          |   |   |   |      |
|----------|---|---|---|------|
| tungsten | - | - | - | 100  |
| oxygen   | - | - | - | 16·6 |

The brown oxide may therefore be properly considered a deutoxide, because  $16\cdot6$  oxygen : 25 oxygen in tungstic acid  $:: 2 : 3$ . From this consideration the atom of tungsten will be 12 ; because  $16\cdot6 : 100 :: 2$  (atoms oxygen) : 12 the atom of tungsten.

68. *Columbium*. This metal forms with oxygen but one known oxide consisting of 100 metal + 5·485 oxygen. Then as  $5\cdot485 : 100 :: 1 : 18\cdot23$ . weight of the atom of columbium.

69. *Nickel*. We are acquainted with two oxides

of nickel; the first, from a mean of the experiments of Tuputi, Rothoff, and Berzelius, is composed of 100 metal + 27.6 oxygen; the second, by the experiments of Rothoff, of 100 nickel + 41 oxygen. These numbers are in the following ratio,  $27.6 : 41 :: 2 : 3$ . Hence, 2 and 3 being the lowest proportional integers of 27.6 and 41, we may take the 2 as representing 2 atoms, and the 3 three atoms. The 27.6 is therefore a deutoxide, viz. 1 atom metal + 2 atoms oxygen, and the 41 a tritoxide of 1 atom metal + 3 atoms oxygen. Hence, these proportions are as

| oxygen. | metal. | weight of 2 ox. | atom nikil. |
|---------|--------|-----------------|-------------|
| 27.6    | : 100  | :: 2            | : 7.305     |
| 41.0    | : 100  | :: 3            | : 7.317     |

Here, the weight of the atom of nickel comes out nearly identical. The mean of  $7.305 + 7.317 \div 2 = 7.311$  weight of the atom of nickel. But others consider the compound 100 metal + 28.74 oxygen a protoxide; in that case the atom of nickel would be only half the weight assigned to it. Dr. Thomson says 3.375, and thinks 100 metal + 29.63 the proper proportions.

70. *Cobalt.* There are two known oxides of cobalt, the blue and the black. From the analysis of Rothoff they appear to be composed of 100 metal + 27.3 oxygen and 100 metal + 40.95 oxygen. Now, these are to each other as 2 to 3, and the weight of the atom of cobalt may be had like that of nickel. It is 7.326.



It is to be observed of cobalt in like manner as of nickel, that its atom will either be 7.326 or half that number, according as we make 100 metal + 27.3 a protoxide, or a deutoxide. Dr. Thomson supposes the peroxide composed of 2 atoms metal + 3 atoms oxygen, which would give the number 3.625; but I think the supposition is inadmissible, because it resolves itself into 1 atom metal + 1.5 atom oxygen.

It will be seen that oxygen unites with nickel and cobalt nearly in the same quantity, and that the weight of the atoms of these metals is almost exactly the same. Generally, if not invariably, it will be found that the weights of atoms are to each other *inversely* as the quantity of oxygen with which equal quantities of each metal combines. Thus, 13.71 weight of an atom of silver is to 25 weight of an atom of mercury as 3.99 oxygen in the protoxide of mercury to 7.272 oxygen in the protoxide of silver. The same will apply to the other states, as they are all multiples of the protoxides. Whence we may infer that where the weight of oxygen is the same in any similar oxides, the weight of the atoms will be the same. The oxides and atoms of nickel and cobalt, considered in either way, are illustrations in point.

71. *Manganese.* According to Dr. John, sulphate of manganese contains 100 parts acid combined with 92.06 parts protoxide of manganese. Hence, from what has been said before concerning the oxygen of

acids and bases combined, 92.06 parts protoxide of manganese contain 20 parts oxygen, and being composed of 1 atom oxygen + 1 atom manganese, we have the following proportions to determine the weight of the atom, as 20 oxygen : (92.06 — 20) 72.06 manganese :: 1 atom of oxygen : 3.603 atom of manganese. From other considerations Dr. Thomson considers 3.500 more near the truth.

72. *Cerium*. The experiments of Hisenger establish two oxides of cerium, composed of 100 metal + 17.42 oxygen and 100 metal + 26.115 oxygen. Now 17.41 : 26.115 :: 2 : 3 hence the 17.41 is a deutoxide, as 2 the lowest proportional integer must represent 2 atoms ; and by its means the weight of the atom of cerium is determined as 17.41 : 100 :: 2 weight of 2 atoms of oxygen : 11.494, the atom of cerium.

73. *Uranium*. There are two oxides of uranium, the first black, the second yellow. According to the experiments of Schoubert, the former consists of 100 uranium + 6.373 oxygen ; and the latter of 100 metal + 9.6 oxygen. These numbers are in the ratio of 2 : 3, the black is therefore a deutoxide, and to obtain the weight of the atom of uranium we say as 6.373 : 100 :: 2 (weight of 2 atoms oxygen) : 31.7 weight of the atom uranium ; or else 15.8.

74. *Zinc*. If the white oxide of zinc be considered a protoxide, we may from its composition of 100

metal + 23.175 oxygen deduce the atom of zinc ; as  
 $23.175 : 100 :: 1 : 4.315$ .

75. *Lead*. If we take the protoxide of lead as composed of 100 metal + 7.692 oxygen, the atom of lead would come out 13. But if we attend to the different proportions in which oxygen combines with lead, viz. 7.692, 11.03, 15.38, which are to each other as 2, 3, 4 nearly, we will be inclined to consider the 7.692 as constituting the deutoxide, and consequently the weight of the atom will be found twice as great, or  $= 13 \times 2 = 26$  nearly.



## TABLE OF PROPORTIONAL NUMBERS.

The numbers contained in this table are called *proportional*, because they express the ratio in which the substances to which they are affixed combine.

By adding together two simple proportional numbers we get the proportional number of the compound: Thus, 1.125, the proportional number for water, results from the addition of the proportional numbers 1 and 0.125, of oxygen and hydrogen. 2.62 is the proportional number of calcium; by adding 1 to it for oxygen we get 3.62 which is the number for lime; and if to this last there be added 5, which represents sulphuric acid, we shall get 8.62, the proportional number of sulphate of lime, &c.

Oxygen, 1.00.  
Hydrogen, 0.125.  
Boron, 0.33.

+1 oxygen . . . = Water.  
+1 . . . . . = Boracic acid.  
+1 . . . . . = Oxide of carbon.

Carbon, 0.765.

+2 . . . . . = Carbonic acid.  
+0.125 hydro. = Carbonated hydrogen.

+0.75 oxygen. = Hypophosphorous acid.  
+1.5 . . . . . = Phosphorous acid.

Phosphorus, 1.5.

+2.5 . . . . . = Phosphoric acid.  
+6.6 chlorine. = Proto chloruret.  
+11.0 . . . . . = Deuto chloruret.

+2 oxygen . . . = Sulphurous acid.

Sulphur, 2

+3 . . . . . = Sulphuric acid.

+0.125 hydro. = Hydro sulphuric acid.

Sulphur, 4.

+0.765 carbon = Carburet of sulphur.

Sulphur, 2.

+4.4 chlorine. = Chloruret of sulphur.

+5. oxygen . . = Iodic acid.

Iodine, 15.62.

+0.125 hydrog. = Hydriodic acid.

+0.585 nitrog. = Ioduret of nitrogen.

#### Composition of the Salts.

2.765 carbonic acid + 1 part of a base containing 1 oxygen, form a sub carbonate. The number 2.765 must be doubled for the saturated carbonates.

3 phosphorous acid + a quantity of any base having 1 oxygen, form a neutral phrophite.

4 phosphoric acid + a quantity of base having 1 oxygen form a neutral phosphate. For the subphosphates or the acid phosphates, 4 the number for the phosphoric acid must be multiplied by 2, the quantity of base remaining the same.

4 sulphurous acid + a quantity of base having 1 oxygen form a neutral sulphite.

5 sulphuric acid + a quantity of base having 1 oxygen form a neutral sulphate.

2.125 hydro sulphuric acid + a quantity of base having 1 oxygen form a neutral hydro-sulphate.

20.62 iodic acid + a quantity of base having 1 oxygen form a neutral iodate.

15.745 hydriodic acid + a quantity of base, having 1 oxygen, form a neutral hydriodate.



|                           |   |  |   |  |
|---------------------------|---|--|---|--|
| <i>Chlorine</i> , 44.     | { | + 1 oxygen . . . = Protoxide of chlorine.              | { | 9.4 chloric acid + a quantity of base, having 1 oxygen, form a neutral chlorate.             |
|                           |   | + 4 . . . . . = Deutox. ditto.                         |   |  |
|                           |   | + 5 . . . . . = Chloric acid.                          |   |  |
|                           |   | + 1.765 ox. of carbon . . . . = Chloroxycarbonic acid. |   |  |
|                           |   | + 0.125 hydrog. = Hydrochloric acid.                   |   |  |
| <i>Nitrogen</i> , 1.75.   | { | + 1 oxygen . . . = Protoxide of nitrogen.              | { | 4.525 hydrochloric acid + a quantity of base, having 1 oxygen, form a neutral hydrochlorate. |
|                           |   | + 2 . . . . . = Deutoxide.                             |   |  |
|                           |   | + 3 . . . . . = Hyponitrous acid.                      |   |  |
|                           |   | + 4 . . . . . = Nitrous acid.                          |   |  |
|                           |   | + 5 . . . . . = Nitric acid.                           |   |  |
| <i>Arsenic</i> , 4.75.    | { | + 1.63 carbon = Cyanogen.                              | { | 6.75 nitric acid + a quantity of base having 1 oxygen form a neutral nitrate.                |
|                           |   | + 0.375 hydrog. = Ammonia                              |   |  |
|                           |   | + 1.5 oxygen . . = Oxide of arsenic.                   |   |  |
|                           |   | + 2.5 . . . . . = Arsenic acid.                        |   |  |
|                           |   | + 3 . sulphur . = Sulphuret of arsenic.                |   |  |
| <i>Molybdenum</i> , 6.    | { | + 6.6 chlorine. = Chloruret of ditto.                  | { | 7.25 arsenic acid + a quantity of base having 1 oxygen form a neutral arsenate.              |
|                           |   | + 23.43 Iodine. = Ioduret of do.                       |   |  |
|                           |   | + 2 oxygen . . . = Oxide of molybdenum.                |   |  |
|                           |   | + 3 . . . . . = Molybdic acid.                         |   |  |
|                           |   | + 4 sulphur . . . = Sulphuret of molybdenum.           |   |  |
| <i>Chromium</i> , 3.5.    | { | + 1.5 oxygen . . = Oxide of chromium                   | { | 9. molybdic acid + a quantity of base having 1 oxygen form a neutral molybdate.              |
|                           |   | + 3 . . . . . = Chromic acid.                          |   |  |
| <i>Tungsten</i> , 12.     | { | + 1.5 oxygen . . = Oxide of Tungsten.                  | { | 6.5 chromic acid + a quantity of base, having 1 oxygen, form a neutral chromate.             |
|                           |   | + 3 . . . . . = Tungstic acid.                         |   |  |
| <i>Columbium</i> , 18.23. | { | + 1 oxygen . . . = Columbic acid.                      | { | 15 Tungstic acid + a quantity of base, having 1 oxygen, from a neutral tungstate.            |
| <i>Silicium</i> ,         | { | + 1 oxygen . . . = Silex.                              | { | 19.23 columbic acid + a quantity of base, having 1 oxygen, from a neutral columbate.         |
| <i>Zirconium</i> , 4.625. | { | + 1 oxygen . . . = Zircon.                             | { |  |

|                           |   |
|---------------------------|---|
| <i>Aluminum</i> , 1·115.  | +1 oxigen . . . = Alumine.                |
| <i>Glucinum</i> , 2·205.  | +1 . . . . . = Glucine.                   |
| <i>Yttrium</i> , 4        | +1 . . . . . = Yttria.                    |
| <i>Calcium</i> , 2·62.    | +1 oxigen . . . = Lime.                   |
|                           | +4·4 chlorine . = Chloruret of calcium.   |
|                           | +15·62 iodine . = Ioduret of do.          |
| <i>Magnesium</i> , 1·5.   | +1 oxigen . . . = Magnesia.               |
|                           | +4·4 chlorine . = Chloruret of magnesium. |
|                           | +15·62 iodine . = Ioduret of do.          |
| <i>Strontium</i> , 5·5.   | +1 oxigen . . . = Strontian.              |
|                           | +4·4 chlorine . = Chloruret of strontium. |
|                           | +15·62 iodine . = Ioduret of do.          |
| <i>Barium</i> , 8·73.     | +1 oxigen . . . = Barytes.                |
|                           | +4·4 chlorine . = Chloruret of Barium.    |
|                           | +15·62 iodine . = Ioduret of Barium.      |
| <i>Sodium</i> , 6·006.    | +1 oxigen . . . = Soda.                   |
|                           | +1·5 . . . . . = Peroxide of sodium.      |
|                           | +4·4 chlorine . = Chloruret of do.        |
| <i>Potassium</i> , 5·0.   | +15·62 iodine . = Ioduret of do.          |
|                           | +1 oxigen . . . = Potassa or potash.      |
|                           | +3 . . . . . = Peroxide of Potassium.     |
| <i>Manganesec</i> , 3·603 | +4·4 chlorine . = Chloruret of do.        |
|                           | +15·62 iodine . = Ioduret of do.          |
|                           | +1 oxigen . . . = Protoxide.              |
| <i>Zinc</i> , 4·315.      | +1·5 . . . . . = Deutoxide.               |
|                           | +2 . . . . . = Peroxide.                  |
|                           | +4·4 chlorine . = Chloruret of manganes.  |
|                           | +1 oxigen . . . = Protoxide.              |
|                           | +2 sulphur . . = Sulphuret.               |
|                           | +4·4 chlorine . = Chloruret.              |
|                           | +15·62 iodine . = Ioduret.                |

|                         |   |                                    |
|-------------------------|---|------------------------------------|
| <i>Iron</i> , 3·45.     | { | + 1 . oxigen . . = Protoxide.      |
|                         |   | + 1·5 . . . . . = Peroxide.        |
|                         |   | + 2 . sulphur . = Protosulphuret.  |
|                         |   | + 4 . . . . . = Deutosulphuret     |
|                         |   | + 4·4 chlorine . = Chloruret.      |
| <i>Tin</i> , 7·352.     | { | + 15·26 iodine . = Ioduret.        |
|                         |   | + 1 . oxigen . . = Protoxide.      |
|                         |   | + 2 . . . . . = Deutoxide.         |
|                         |   | + 2 . sulphur . = Protosulphuret.  |
|                         |   | + 4 . . . . . = Deutosulphuret.    |
| <i>Antimony</i> , 10·75 | { | + 4·4 chlorine . = Protochloruret. |
|                         |   | + 8·8 . . . . . = Deutochloruret.  |
|                         |   | + 15·62 iodine . = Ioduret.        |
|                         |   | + 1 . oxigen . . = Protoxide.      |
|                         |   | + 1·41 . . . . . = Deutoxide.      |
| <i>Uranium</i> , 31·70. | { | + 2 . . . . . = Peroxide.          |
|                         |   | + 4·4 chlorine . = Chloruret.      |
|                         |   | + 2 sulphur . . = Sulphuret.       |
|                         |   | + 15·6 iodine . = Ioduret.         |
|                         |   | + 1 oxigen . . . = Protoxide.      |
| <i>Cerium</i> , 11·494. | { | + 1·5 . . . . . = Deutoxide.       |
|                         |   | + 1 oxigen . . . = Protoxide.      |
|                         |   | + 1·5 . . . . . = Deutoxide.       |
|                         |   | + 4·4 chlorine . = Chloruret.      |
|                         |   | + 1 oxigen . . . = Protoxide.      |
| <i>Cobalt</i> , 7·326.  | { | + 1 3 . . . . . = Deutoxide.       |
|                         |   | + 4·4 chlorine . = Chloruret.      |
|                         |   | + 1 oxigen . . . = Oxide.          |
|                         |   | + 2 sulphur . . = Sulphuret.       |
|                         |   | + 4·4 chlorine . = Chloruret.      |
| <i>Bismuth</i> , 8·758. | { | + 15 62 iodine . = Ioduret.        |
|                         |   | + 1 oxigen . . . = Protoxide.      |
|                         |   | + 2 . . . . . = Deutoxide.         |
|                         |   | + 2 sulphur . . = Sulphuret.       |
|                         |   | + 4·4 chlorine . = Chloruret.      |
| <i>Copper</i> , 8·0.    | { | (Proto.)                           |
|                         |   | + 8·8 . . . . . = Deutochloruret.  |
|                         |   | + 15·65 iodine . = Ioduret.        |

|                           |   |
|---------------------------|---|
| <i>Tellurium</i> , 3·593. | + 1· oxygen . . . =Oxide.                       |
|                           | + 4·4 chlorine . =Chloruret.                    |
|                           | + 0·125 hydrog =Hydrogeneted<br>gen. Tellurium. |
| <i>Nickel</i> , 7·311.    | + 1 oxygen . . . =Protoxide.                    |
|                           | + 1·5 . . . . . =Deutoxide.                     |
|                           | + 4·4 chlorine . =Chloruret.                    |
| <i>Lead</i> , 26·0.       | + 1 oxygen . . . =Protoxide.                    |
|                           | + 1·5 . . . . . =Deutoxide.                     |
|                           | + 2 . . . . . =Tritoxide.                       |
|                           | + 2 sulphur . . =Sulphuret.                     |
|                           | + 4·4 chlorine . =Chloruret.                    |
|                           | + 15·62 iodine . =Ioduret.                      |
|                           | + 1 oxygen . . =Protoxide.                      |
| <i>Mercury</i> , 25·0.    | + 2 . . . . . =Deutoxide.                       |
|                           | + 2 sulphur . =Sulphuret,<br>(Proto.)           |
|                           | + 4 . . . . . =Deutosulphu-<br>ret.             |
|                           | + 4·4 chlorine . =Protochloru-<br>ret.          |
|                           | + 8·8 . . . . . =Deutochloru-<br>ret.           |
|                           | + 15·62 iodine . =Protoioduret.                 |
|                           | + 31·24 . . . . =Deutoioduret.                  |
| <i>Silver</i> , 13·71.    | + 1 . oxygen . . =Oxide.                        |
|                           | + 2 sulphur . . =Sulphuret                      |
|                           | + 4·4 chlorine . =Chloruret                     |
|                           | + 15·62 iodine . =Ioduret.                      |
| <i>Palladium</i> , 8·333. | + 1 oxygen . . =Oxide.                          |
|                           | + 2 sulphur . . =Sulphuret.                     |
|                           | + 4·4 chlorine . =Chloruret.                    |
|                           | + 1 oxygen . . =Protoxide.                      |
| <i>Gold</i> , 24·96.      | + 2 . . . . . =Deutoxide.                       |
|                           | + 4 sulphur . . =Deutosulphu-<br>ret.           |
|                           | + 8·8 chlorine . =Deutochloru-<br>ret.          |
|                           | + 1 . oxygen . =Protoxide.                      |
| <i>Platinum</i> , 23·625. | + 2 . . . . . =Deutoxide.                       |
|                           | + 8·8 chlorine . =Deutochloru-<br>ret.          |
|                           | + 2 sulphur . . =Sulphuret.                     |
| <i>Iridium</i> , 6.       |   |



The weight of each inflammable substance in this table is in general such, that in uniting to one part of oxygen, it passes to the first degree of oxidation. But the rule has been departed from in regard to phosphorus, sulphur, iodine, arsenic, molybdenum, chromium, tungsten. For each of these the representative number is taken from such a weight of its acid as can saturate a base containing 1 part oxygen. This renders the table more short and convenient, because it leaves nothing to do except adding the number that represents the weight of an acid (found in the table) to the number representing any base whatever, (found also in the table) in order to get the proportions of all the salts.

For example, by adding 5 sulphuric acid, or 4 of sulphurous acid to 3.62 lime, we get the sulphate or the sulphite of lime.

Dr. Wallaston has made an arrangement of proportional numbers, which he calls a *synoptic scale of chymical equivalents*, that exhibits in a very condensed form the constituents of a great many compound bodies.

When a chymist subjects a saline substance to analysis, the questions to be answered are so many and various, that he is seldom disposed to undertake, by himself, the necessary series of experiments, if he can rely with confidence on the labours of his predecessors.

Let the chrystallized sulphate of copper be the subject of analysis, and the questions to be resolved are these. How much does it contain of sulphuric acid? How much oxide of copper? How much water? We may wish to know further the quantity of sulphur, of copper, of oxygen, of hydrogen.

It may be necessary to consider, likewise, how much of the different reagents must be employed to discover the proportion of sulphuric acid; for instance, how much barytes, carbonate of barytes, or nitrate of barytes; or how much lead in the form of nitrate. And after having obtained the precipitates of sulphate of barytes and sulphate of lead, it is still necessary to find the proportion of dry sulphuric acid which they respectively hold.

We may wish to verify these results by ascertaining the precise quantity of pure potash or carbonate of potash required for the precipitation of the copper. Lastly, zinc or iron may be used for the same purpose, and then it will, perhaps, be desirable to know how much sulphate of zinc or sulphate of iron remains in solution.

Were we to resolve many such questions we would find it to be extremely fatiguing, and to waste a great deal of time; whereas, a considerable deal of both is saved to the experimental chymist, whenever he can have recourse to a prior analysis that is executed with all due care and accuracy.

The synoptic scale of chymical equivalents resolves all these questions by bare inspection, as relates to many of the salts contained in the table. It not only gives the numerical proportions, on which the desired solution is calculated, but it expresses the precise weights of the different constituents of a given quantity of the salt under examination, no less than the quantity of the reagents necessary for its analysis, and that of the precipitates which each of them throws down. Such a scale could not be formed without a previous determination of the proportions in which the different known bodies unite, and without their being expressed in such terms that the same substance would be always represented by the same number.

This mode of designation is due to Richter; he also was the first who observed the law of constant proportions on which alone these numerical representations can be founded.

By the theory of Dalton, which is the one that best explains the phenomena; chymical saturation results from the union of a single atom of each of the combining bodies; and where one of the constituents is in excess, then two or more atoms of this combine with a single atom of the other.

According to this view of the subject, when we count the relative weights of the equivalents, Mr.

Dalton conceives that we count the united weight of a given number of atoms, and consequently include the proportion which exists between the ultimate molecules of each of these substances. But, in the case of two combinations of the same substances, since it is difficult to determine which of them is the compound of one pair of simple atoms; and since the decision of this question affects only the theory, without being at all necessary to the formation of a table intended for practical use, Dr. Wollaston has taken no pains to make his numbers correspond with the hypothesis of atoms. His object has been to render his table practical, and he considers the doctrine of simple multiples, on which the theory of atoms is founded, as only means of determining, by division, those quantities that do not precisely coincide with the law of Richter.

Dr. Wollaston took for the basis of his calculations and real measure of comparison for determining equivalents, a determinate quantity of carbonate of lime. This is a perfectly neutral compound; it is easily obtained in a state of uniform purity and easily analyzed as a binary compound. It is the most suitable measure of the power of the acids, and furnishes the most precise expression of the comparative neutralizing power of the alcalies.

The first thing, consequently, to be done was to determine the number that should represent the re-



lative weight of carbonic acid, when oxygen is represented by 10. But it is a thing satisfactorily proved that a determinate quantity of oxygen gives an exactly equal volume of carbonic acid by uniting with carbon; and as the specific gravity of these gases is as 10 to 13·77, or as 20 to 27·54, the weight of carbon is given exactly equal to 7·54, which in this combination with 20 oxygen forms the deutoxide. The protoxide of carbon is represented by 17·54.

Carbonic acid being, therefore, represented by 27·54, it results from the analysis of carbonate of lime, which, during calcination loses 43·7 acid, and leaves 56·3 base per cent., that these two substances are combined in the proportion of 27·54 to 35·46; and consequently that lime should be represented by 35·46, and carbonate of lime by 63.

If the series of decompositions be now continued in order to verify the preceding analysis, 63 parts of carbonate of lime may be dissolved in muriatic acid, and after evaporating the solution to perfect dryness, we obtain 69·56 of muriate of lime; and by subtracting 35·46, weight of the lime, we get a difference of 34·1, which represents the amount of dry muriatic acid.

But lime is known to be a metallic substance united to oxygen, this salt may, consequently, be considered under another point of view, as a binary compound, an oxi-muriate of calcium. In this case

we must transfer the 10 oxygen to the muriatic acid, and the combination will read 44.1 oxi-muriatic acid combined with 26.46 calcium,  $\therefore = 69.56$ . Or else, if we consider it as a chloride of calcium, its value, on the scale of numbers, will still remain 69.56, whether we call it oxi-muriatic acid, deplogisticated marine acid, or chlorine; for the portion of matter added to the calcium is always the same, and represented by 44.1. This number, consequently, represents a mere fact, which is independent of any theory; but which enables us to estimate the proportion of constituents in every muriatic combination, without discussing their simple or compound nature, a question still undecided.

In like manner the muriates of potassa and soda will find their place on the scale of equivalents, and the relative weights of pure potassa and soda can be determined with the greatest exactness, because they are not susceptible of an excess of acidity, or of decomposition by heat.

If to a quantity of muriatic acid, which can just dissolve 100 parts of carbonate of lime, there be added 100 grains of crystallized carbonate of potassa, and that after this addition the acid can no longer dissolve more than 49.8 of carbonate of lime, it follows that 100 crystallized carbonate of potassa are the chymical equivalent of 50.2 of carbonate of lime, and

consequently that 125.5 are the equivalent of 63 on the scale.  $50.2 : 100 :: 63 : 125.5$ .

In the next place, if 125.5 crystallized carbonate of potassa be combined with muriatic acid to excess, and that the solution is evaporated until all the water and the redundant acid is driven off, there will remain 93.2 of neutral salt, whether it be called muriate of potassa, or chloride of potassium, or by whatever name designated it will always yield 34.1 of dry acid ; consequently, the value of the potassa is 59.1. This will contain but 49.1 potassium, which requires 1 of oxygen.

Another important consideration relates to the composition of the crystallized carbonate of potassa, which Dr. Wollaston, with great propriety, calls bicarbonate of potassa. This name distinctly marks the difference between it and the subcarbonate, and recalls the double dose of carbonic acid which it contains. When compared with the carbonate of lime it is even necessary to consider it as a supercarbonate, for if a solution of this salt be added to a neutral solution of carbonate of lime, there arises a strong effervescence, owing to the carbonic acid exceeding the quantity necessary for the saturation of the lime. When 125.5 parts of bicarbonate of potassa are saturated with nitric acid, and all due care is taken to prevent any loss of fluid with the gas that escapes, the loss of carbonic acid is 55, or the double of 27.5. But if,

before saturation, the salt has been exposed to a low red heat it sustains a loss of 38.8, viz. 27.5 carbonic acid, and 11.3 of water, after which the addition of an acid drives off but 27.5, or a single proportion of carbonic acid.

The scale of chymical equivalents is now commonly sold in the book stores of this city, and I cannot too strongly recommend its use. A frequent inspection of it will remind the student of many proportions which he would otherwise forget, and, as an exercise, it will familiarize him with the most important chymical combinations.

To the practical chymist it gives the composition of any weight whatever of any of the salts contained on the scale, the quantity of any other salt necessary to decompose it, the quantity of the new salt that will be formed, and many other similar things that are perpetually occurring.

The scale itself has various simple and compound substances set down on both sides of a slider that moves through it longitudinally. To these substances numbers are annexed, and, by motion of the slider, numerous combinations may be quickly determined, without the intervention of calculation. There are 2 positions of the slider.

In the first, 10 on the slider is brought opposite to oxygen on the scale, and other bodies are in their due proportion to oxygen, so that carbonic acid being



27·54 and lime 35·46, carbonate of lime is placed at 63.

In like manner, the weight of oxygen being 10, the proportional weight of sulphur is 20, azote 17·5, &c. and by simple addition of the proportional weights of the single bodies on the scale we get those of the compounds. Magnesia is 25, sulphuric acid 50, and sulphate of magnesia 75, on the scale ; therefore, 75 dry sulphate of magnesia is composed in the proportion of 25 base and 50 acid.

Carbonic acid being 27·54 and ammonia 21·5, subcarbonate of ammonia is placed at 49·4 and is composed in this proportion.

Muriatic acid gas being 45·5, and ammonia 21·5, they combine in the gaseous state, and muriate of ammonia is 67.

Oxide of silver being 145·5, and dry muriatic acid 34·5, muriate of silver is 180.

Oxide of copper is 50, and sulphuric acid is 50, but crystallized sulphate of copper contains water of crystallization, and oxygen being ten, the proportion in which water stands to it is 11·4 which multiplied by 5, the proportion in which the water of crystallization stands to dry sulphate of copper, makes 57, added to 100 = 157 the number on the scale.

Oxide of zinc is 51, and sulphuric acid 50, which + 79 water of crystallization, makes 180, the number on the scale.

Lead on the scale is placed opposite to 129.8 in this position of the slider. The addition of 10 oxygen and 34.4 dry muriatic acid give 174, the number for muriate of lead on the scale.

Lastly, mercury is 126.6, and oxygen being 10, dry muriatic acid 34.4, as above, corrosive muriate and of mercury is placed opposite to 170 on the slider.

*Second position of the slider.*

If it be required to find the weights of the constituents of a given compound, say 100 oxide of iron, the slider is to be moved until 100 comes against oxide of iron. Then the numbers on the slider opposite the constituents, oxygen and iron, is the quantity of each in 100 of the compound. For oxygen it is 22.5, and for iron 77.5.

It also gives the constituents of sulphate of iron per cent, as composed of oxide of iron 25.8, sulphuric acid 28.2, water of crystallization 46.

Let there be given a quantity of any salt, how much will be given of any other, having a constituent the same as one in the given salt?

Let bicarbonate of soda be the salt given. When the scale is adjusted, 100 being opposite to bicarbonate of soda, and salts having the same base, (soda) are sought for, it will be seen immediately that these 100 parts bicarbonate contain as much soda as 84.5 dry sulphate of soda; 69.5 muriate of soda; 63 subcarbonate of soda; 101 nitrate of soda, &c.

Or, if salts having the same acid and the same quantity be required, the following will be found on the scale, viz. 46.5 subcarbonate of ammonia; 75.5 bicarbonate of ammonia; 60 carbonate of lime; 118.8 carbonate of barytes, &c. Moreover, it will be seen on the scale by looking at soda, that *all* the first named salts contain 37 soda, and all the last named 26.2 carbonic acid.

It is not always necessary to place the slider at 100. For any acid, as 50 sulphuric acid, move the slider until sulphuric acid on the scale stands opposite 50 on the slider, and the numbers opposite the constituents of the acid, marked on the scale, will give their proportional weights in 50 of the acid; according to this the oxygen will be 30 and the sulphur 20.

For any salt, as 60 carbonate of lime, when 60 stands opposite the carbonate of lime, the constituents will be 26.3 acid + 33.7 base. If the slider had been placed at 100 carbonate of lime in the usual way, the acid would be 43 and the base 56, but these numbers for 100, are in precisely the same proportion as the former for 60.

I will conclude this view of the valuable scale of chymical equivalents by an example taken from Dr. Wollaston's paper, in the philosophical transactions for 1814, part 1st.

“ In the second figure, the slider is represented drawn upwards till 100 corresponds to muriate of

soda; and accordingly the scale then shows how much of each substance contained in the table is equivalent to 100 of common salt. It shows, with regard to the different views of the analysis of this salt, that it contains 46·5 dry muriatic acid, and 53·4 of soda, or 39·8 sodium, and 13·6 oxygen; or if viewed as chloride of sodium, that it contains 60·2 chlorine, and 39·8 sodium. With respect to reagents, it may be seen that 283 nitrate of lead, containing 191 of litharge employed to separate the muriatic acid, would yield a precipitate of 237 muriate of lead, and that there would then remain in solution nearly 146 nitrate of soda. It may at the same time be seen, that the acid in this quantity of salt would serve to make 232 corrosive sublimate, containing 185·5 red oxide of mercury; or would make 91·5 muriate of ammonia, composed of 62 muriatic gas (or hydromuriatic acid) and 29·5 ammonia. The scale shows also, that for the purpose of obtaining the whole of the acid in distillation the quantity of oil of vitriol required is nearly 84, and that the residuum of this distillation would be 122 dry sulphate of soda, from which might be obtained, by crystallization, 277 of Glauber salt containing 155 water of crystallization. These and many more such answers appear at once by bare inspection, as soon as the weight of any substance intended for examination is made by motion of the slider correctly to correspond with its place in the adjacent column.

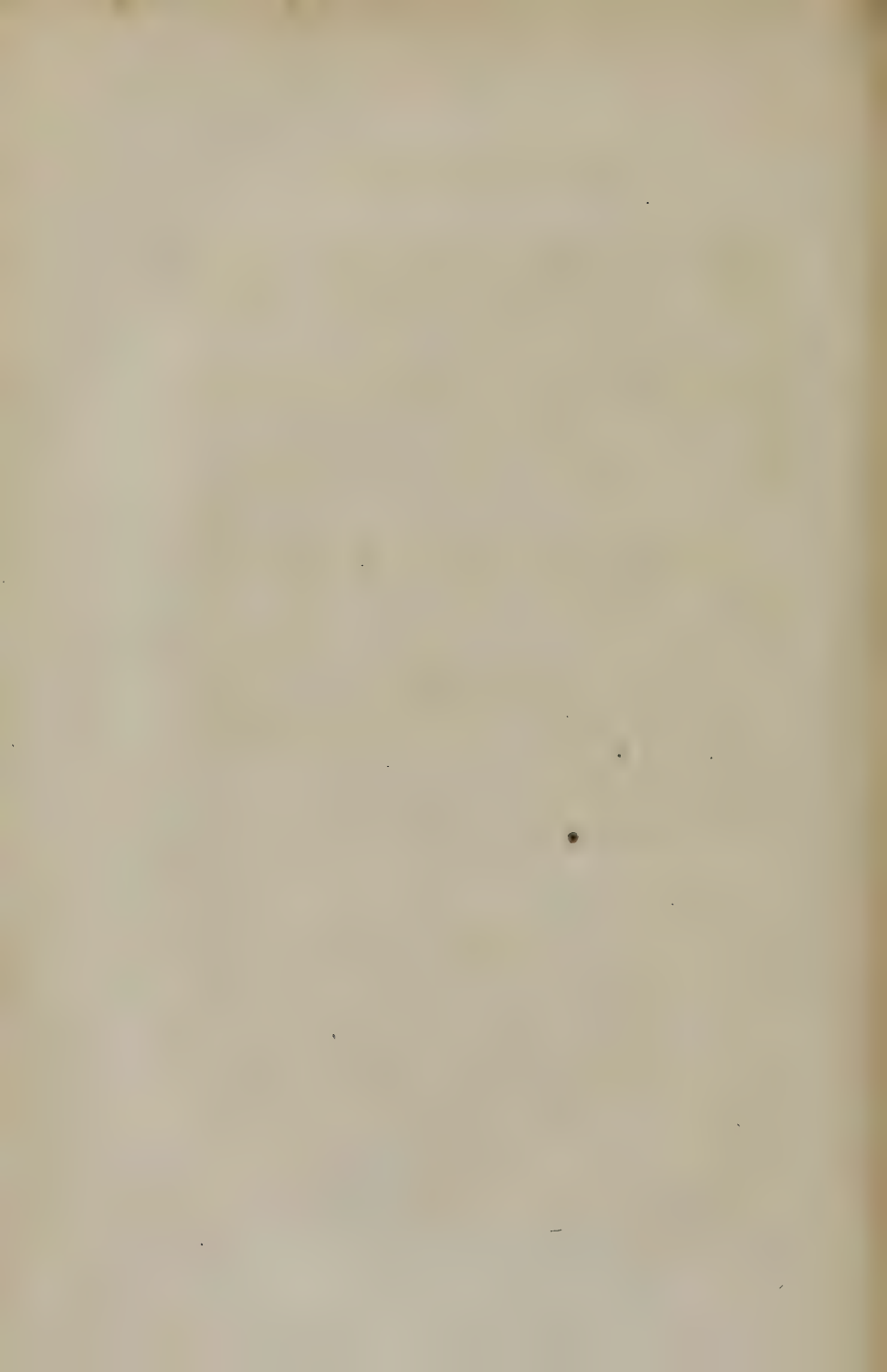


*Dr. Wollaston's Numerical Table of Chymical Equivalents is subjoined for the convenience of those who make use of his scale.*

|                                     |        |                                |        |
|-------------------------------------|--------|--------------------------------|--------|
| 1. Hydrogen . . . . .               | 1.32   | Bi-carbonate ( + 27.5 C. A.    |        |
| 2. Oxygen . . . . .                 | 10.00  | + 11.3 water) . . . .          | 105.50 |
| 3. Water . . . . .                  | 11.32  | 34. Sub-carbonate of potash .  | 86.00  |
| 4. Carbon . . . . .                 | 7.54   | Bi-carbonate ( + 27.5 C. A.    |        |
| 5. Carbonic acid ( + 20 oxygen)     | 27.54  | + 11.3 water) . . . .          | 125.50 |
| 6. Sulphur . . . . .                | 20.00  | 35. Carbonate of lime . . .    | 63.00  |
| 7. Sulphuric acid ( + 30 oxygen)    | 50.00  | 36. ————— barytes . .          | 124.50 |
| 8. Phosphorus . . . . .             | 17.40  | 37. ————— lead . . . .         | 167.00 |
| 9. Phosphoric acid ( + 20 oxygen)   | 37.40  | 38. Sulphuric acid dry . . .   | 50.00  |
| 10. Azote or Nitrogen . . . .       | 17.54  | 39. Do. s. g. 1.850 (50 + 11.3 |        |
| 11. Nitric acid ( + 50 oxygen)      | 67.54  | water) . . . . .               | 61.30  |
| 12. Muriatic acid dry . . . .       | 34.10  | 40. Sulphate of soda ( + 10    |        |
| 13. Oxymuriatic acid ( + 10 oxygen) | 44.10  | waters = 113.2) . . . .        | 202.30 |
| 14. Chlorine 44.10 + 132 hy.        | 45.42  | 41. Sulphate of potash . . .   | 109.10 |
| = muriatic acid gas . . . .         | 45.42  | 42. Sulphate of magnesia dry   | 74.60  |
| 15. Oxalic acid . . . . .           | 47.0   | Do. Chrystallized ( + 7 wa-    |        |
| 16. Ammonia . . . . .               | 21.5   | ters = 79.3) . . . . .         | 153.90 |
| 17. Soda . . . . .                  | 39.1   | 43. Sulphate of lime dry . .   | 85.50  |
| 18. Sodium ( — 10 oxygen) . .       | 29.1   | Chrystallized ( + 2 waters     |        |
| 19. Potash . . . . .                | 59.1   | = 22.64) . . . . .             | 108.10 |
| 20. Potassium ( — 10 oxygen)        | 49.1   | 44. Sulphate of strontites . . | 119.00 |
| 21. Magnesia . . . . .              | 24.6   | 45. ————— barytes . .          | 147.00 |
| 22. Lime . . . . .                  | 35.46  | 46. ————— copper (1 acid       |        |
| 23. Calcium ( — 10 oxygen) . .      | 25.46  | + 1 oxide + 5 water) . .       | 156.60 |
| 24. Strontites . . . . .            | 69.00  | 47. ————— iron (7 water)       | 173.80 |
| 25. Barytes . . . . .               | 97.00  | 48. ————— zinc (do) . . .      | 180.20 |
| 26. Iron . . . . .                  | 34.5   | 49. ————— lead . . . . .       | 189.50 |
| Black oxide ( 10 oxygen) . .        | 44.50  | 50. Nitric acid dry . . . .    | 67.54  |
| Red oxide ( + 15 oxygen) . .        | 49.50  | Do. s. g. 1.50 ( + 2 water     |        |
| 27. Copper . . . . .                | 40.00  | = 22.64) . . . . .             | 90.20  |
| Black oxide ( + 10 oxygen) . .      | 50.00  | 51. Nitrate of soda . . . .    | 106.60 |
| 28. Zinc . . . . .                  | 41.00  | 52. ————— potash . . . .       | 126.60 |
| Oxide ( + 10 oxygen) . . . .        | 51.00  | 53. ————— lime . . . . .       | 103.00 |
| 29. Mercury . . . . .               | 125.50 | 54. ————— barytes . . . .      | 164.50 |
| Red oxide ( + 10 oxygen) . .        | 135.50 | 55. ————— lead . . . . .       | 207.00 |
| Black oxide ( + 125.5               |        | 56. Muriate of ammonia . .     | 66.90  |
| mercury) . . . . .                  | 261.00 | 57. ————— soda . . . . .       | 73.20  |
| 30. Lead . . . . .                  | 129.50 | 58. ————— potash . . . .       | 93.20  |
| Litharge ( + 10 oxygen) . .         | 139.50 | Oxymuriate of do. ( + 60       |        |
| 31. Silver . . . . .                | 135.00 | oxygen) . . . . .              | 153.20 |
| Oxide ( + 10 oxygen) . . . .        | 145.00 | 59. Muriate of lime . . . .    | 69.60  |
| 32. Sub-carbonate of ammonia        | 49.00  | 60. ————— barytes . . . .      | 131.00 |
| Bi-carbonate ( + 27.5 car-          |        | 61. ————— lead . . . . .       | 173.60 |
| bonic acid) . . . . .               | 76.50  | 62. ————— silver . . . .       | 179.10 |
| 33. Sub-carbonate of soda . .       | 66.60  | 63. ————— mercury . . . .      | 170.10 |
|                                     |        | 64. Sub-muriate of do. (1 acid |        |
|                                     |        | + 1 oxygen + 2 merc.) . .      | 296.10 |
|                                     |        | 65. Phosphate of lead . . . .  | 176.90 |
|                                     |        | 66. Oxalate of lead . . . . .  | 186.50 |
|                                     |        | 67. Bin-oxalate of potash . .  | 153.00 |

## APPENDIX.

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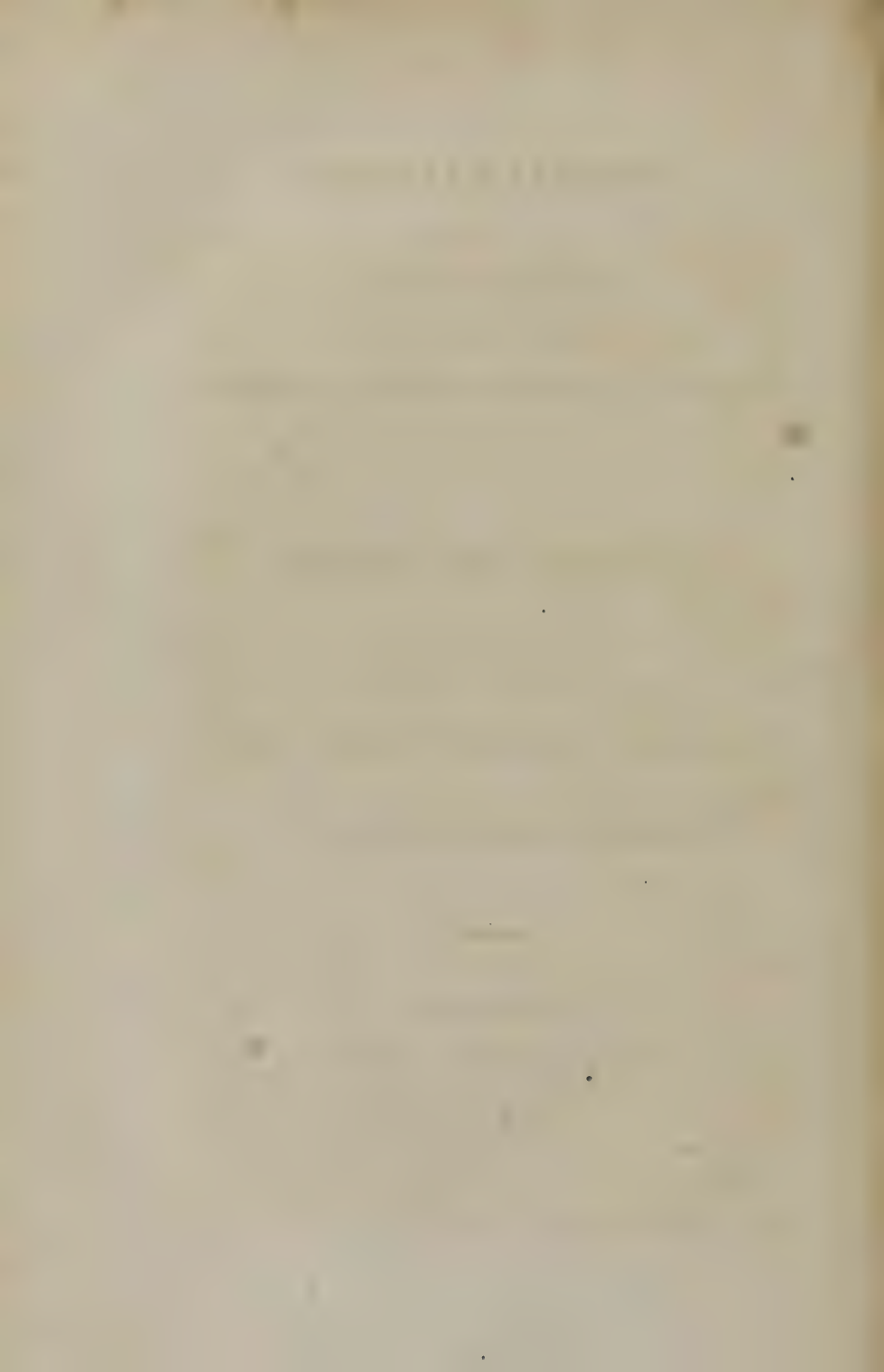
**CHYMICAL EXERCISES,**  
  
**IN THE LABORATORY OF THE**  
  
**COLLEGE OF PHYSICIANS AND SURGEONS,**  
  
**BY**  
  
**THE PUPILS OF THE LABORATORY,**  
  
**UNDER THE DIRECTION OF**  
  
**THE PROFESSOR OF CHYMISTRY AND MATERIA MEDICA,**  
  
**WILLIAM JAMES MACNEVEN.**



**NEW-YORK :**  
  
**PRINTED BY GRATTAN AND BANKS,**  
*Corner of Nassau & Spruce Streets,*

.....  
**1819.**





## CHYMICAL EXERCISES, &c.



The chymical exercises in the laboratory of the College of Physicians are so directed, that a public communication of the labours of the operating pupils may, now and then, be acceptable to all those learned persons, who look with any degree of interest to the progress of chymical and mineralogical studies in this country. The present sheet affords a specimen of the mode of proceeding and of what may be expected from young Physicians so instructed, if they should choose, hereafter, to continue their attention to the same pursuits.

The dolomite of the first analysis was taken up on Manhattan Island from the great marble quarry near Kingsbridge. The limestone district adjacent to Kingsbridge is shewn, by the character of its minerals and the position of its strata, to be chiefly primitive. The marble extends two or three miles into the county of New-York, and is the termination of a range of primitive granular limestone that commences in Canada, runs through the western parts of

New England, and arrives in our neighbourhood through West Chester county. The direction of this range is nearly parallel with the primitive strata of New-England and New-York, running from north-east to south-west.

The granular limestone of Kingsbridge is stratified, presenting an inclination to the south-east, of from sixty to seventy degrees, as determined by Mr. Pierce. It is crossed by vertical veins of granite and quartz, from a few inches to a foot in width. They extend from the summit of the rock to the lowest depths yet penetrated, dividing the quarries into distinct sections. Mr. Pierce looks upon this circumstance as one that affords additional evidence of the primitive character of this region. Veins of granite having seldom, if ever, been seen elsewhere in limestone, must here be considered as of more recent formation than the rock they traverse.

The surface of the quarry at Kingsbridge appears in most places in a state of disintegration, resembling salt. In general, a short distance below the surface, the limestone becomes more compact and contains most silex. It splits without difficulty into tabular blocks of any dimensions wanted. Though not as fine in grain as the Stockbridge stone, yet it is much used for steps, the fronts of buildings, slabs, &c. Its colour is pretty generally either a greyish or bluish white.

*Minerals.*

The limestone of Kingsbridge embraces pyroxene, tremolite, mica, fetid quartz, oxide of titanium, adularia, tourmaline and sulphuret of iron. The pyroxene, or white augite, is mostly in four-sided elongated tables, the sides of various proportions, and nearly rectangular. Its crystals are sometimes found in eight-sided prisms. Kingsbridge was, for a long time, the only locality for this mineral in the United States, but Mr. Price has lately met with it at Singsing, higher up the Hudson.

The elevation of Spitendevil to the west and Mount-Washington to the south of the calcareous district, exhibit, in place, masses of granite, gneiss, and mica slate. These rocks are the predominant aggregates of the primitive part of the county of New-York. The general direction of the strata is from north-east to south-west, without much regularity of position. It is often observed vertical, sometimes a little inclining to the east, and elsewhere dipping in a contrary direction.

M.

*Analysis of Dolomite from Kingsbridge, by Doctors Theodore and Edwin Gaillard, of South Carolina.*

The specimen which served for this analysis had the following external characters.

White, with a shade of yellow. It forms large masses near the surface, which look like heaps of coarse salt.

It is crystallized in small rhomboidal prisms, with angles of nearly 101 and 79, they form concretions so loosely aggregated as to be easily friable between the fingers.

Without lustre in the mass, but the surfaces of the crystals are shining.

It is easily pulverized.

It effervesces rapidly in nitric acid when pulverized, and in the loose granular state.

Specific gravity, 2.79.

*First Analysis.*

a. 20 grammes of the crystals, were dissolved in dilute muriatic acid, and 950 milligrammes silex and oxide of iron separated.

b. The muriatic solution was concentrated by evaporation, and one-third of its volume of alcohol then added. It was afterwards decomposed by sulphuric acid and the sulphate of lime separated by



the filter, using each time but a small quantity of water for washing it.

*c.* The sulphate of lime obtained in experiment *b*, was converted back into carbonate of lime by boiling with bicarbonate of potassa. When duly dried it weighed 14·87 grammes.

*d.* The sulphate of magnesia formed in experiment *b*, after having been concentrated by evaporation, was converted in like manner into a carbonate, which, dried by the heat of boiling water, gave 3·70 grammes.

|                          |   |       |
|--------------------------|---|-------|
| silex and oxide of iron, | - | ·953  |
| carbonate of magnesia,   | - | 3·70  |
| carbonate of lime,       | - | 14·87 |

---

19·523

loss - - - 477

---

20·000

or in the 100 parts,

|                          |   |       |
|--------------------------|---|-------|
| silex and oxide of iron, | · | 4·765 |
| carbonate of magnesia,   | - | 18·50 |
| carbonate of lime,       | · | 74·35 |

---

97·615

loss, - - - 2·385

---

100·000

*Second Analysis.*

*a.* 20 grammes of the picked crystals were reduced to an impalpable powder and dissolved by little and little in dilute nitric acid, in a florence flask, held in an inclined position, lest any part of the solution should be carried off by the gas during the effervescence. Each addition of the acid caused a brisk effervescence. After this had entirely ceased the solution became quite clear and the whole mineral was seen to have been taken up, except a very small portion lying at the bottom of the flask. Separated by the filter that little exhibited specks of mica, and washed, dried and ignited in a platina crucible, it yielded 1 gramme of silica.

The loss of carbonic acid as determined by a mean of three experiments, was equal to 8.92 grammes.

*b.* A few drops of the solution *a* was tested with ferro-cyanite of potash and found to shew a trace of iron. Ammonia was accordingly added to the entire until the excess of nitric acid became fully saturated. A red precipitate was then seen to float through the fluid, it was collected on a filter of known weight, and dried; it yielded 0.233 milligrammes wholly obeying the magnet.

*c.* The solution *b* freed from iron was crystallized and left extremely bitter crystals, some long

prismatic diverging from a common centre ; others in a confused mass and slightly deliquescent. They were put into a platinum crucible and exposed to a strong red heat until all the nitric acid was driven off.

*d.* The decomposed nitrates of lime and magnesia were then treated with sulphuric acid and converted into sulphates. A little alcohol was added the more effectually to separate the sulphate of lime. This, after being parted by filtration and dried, weighed 25 grammes of hydrated sulphate.

In the present instance, the theoretic composition and the proportional numbers are sufficient to determine the quantity of each base.

Thus, as 100 hydrated sulphate of lime : 33·2 its proportion of lime :: 25 : 8·3,

Also, 56·86 lime : 43·14 its proportion of carbonic acid :: 8·3 : 6·3.

Therefore, 8·3 lime,                    { = 14·6 carbonate of  
+                    6·3 carb. acid,        { lime.

Again, 8·92, the whole quantity of carbonic acid — 6·3 that portion of it joined to the lime is 2·62 the other part in combination with the magnesia, therefore, we say,

As 68·75 carbonic gas : 100 carbonate of magnesia  
:: 2·62 : 3·8.

The mineral is therefore composed of carbonate

|                    |   |   |      |
|--------------------|---|---|------|
| of lime,           | - | - | 14.6 |
| carb. of magnesia, | - | - | 3.8  |
| oxide of iron,     | - | - | .233 |
| silex,             | - | - | 1.   |

---

19.633

|       |   |   |      |
|-------|---|---|------|
| loss, | - | - | .357 |
|-------|---|---|------|

---

20.000

or in hundred parts of carbonate of lime, 73.

carbonate of magnesia 19.

oxide of iron, 1.165

silex, - 5.

---

98.165

|       |   |   |       |
|-------|---|---|-------|
| loss, | - | - | 1.835 |
|-------|---|---|-------|

*Analysis of the Dolomite of Kingsbridge, by John  
Emmet of New-York.*

It having been already well ascertained, by a variety of researches in the laboratory, that this mineral contained no ingredients but those established in the analysis of Doctors T. and E. Gaillard, the object of the present chymical examination was to determine, with as much precision as possible, the proportion of the constituent parts.

*a.* 20 grammes of the mineral, reduced to an impalpable powder, were dissolved in dilute nitric acid, with every precaution to avoid a loss of solid parts. When the effervescence had ceased, a known quantity of water was added until the flask containing the powder and acid was full. By this means the carbonic acid was completely expelled. The difference of the weights of the powder, flask, and solution, before and after mixture, when the effervescence had ceased, gave the quantity of carbonic gas = 8.92 grammes.

*b.* After the fluid had become perfectly clear it was drawn off by means of a fine bulbed syphon, the residue well washed with distilled water, the washing added to the solution, and the inso-



luble part, dried in a red heat, proved to be *silex*, and weighed 23 decigrammes.

*c.* The fluid and washing, *b*, was treated with ammonia in excess; a flacculent precipitate of red oxide of iron was soon formed, which, after separation and drying, weighed 0.24 decigrammes.

*d.* After having duly considered the various modes and the great difficulty of separating lime and magnesia out of the same solution with rigid accuracy, none appeared preferable to that which was already tried, nor any thing more consonant to the principles of chymistry, for obtaining them distinct, than to convert them into two salts, the one of very easy, the other of very difficult solubility. Accordingly, dilute sulphuric acid was put to the solution *b*; it was digested several hours, then boiled a few minutes to favour the more intimate action of the acid and lime on each other. After it became thoroughly clear the supernatant fluid was drawn off by the syphon, and the residuum washed in a small portion of distilled water at a time, until this came through tasteless.

The sulphate thus obtained was carefully dried, transferred to a covered platinum crucible, and exposed, in an air furnace, to an intense heat for one hour. It weighed while yet warm 21 grammes and 65 decigrammes, (dry sulphate.)

By the rule of equivalents this quantity of sulphate is equal to 15.9 carbonate of lime, for it has 8.95 lime, which unites with 6.95 carbonic acid.

*e.* The fluid separated from the sulphate of lime in *d* contained all the magnesia as a sulphate, together with a sulphate of ammonia, formed by the admixture of the sulphuric acid to the nitrate of ammonia existing in the fluid *c*. This was boiled for several minutes with a solution of bicarbonate of potash; there was consequently formed an insoluble carbonate of magnesia and soluble sulphates of potash and ammonia. While still hot, the whole was filtered, and the carbonate of magnesia separated. Dried in the heat of boiling water it weighed 3.65 grammes.

The same result obtained here by experiment may also be derived from the scale of equivalents. The carbonic acid contained in both lime and magnesia was 8.92 (vid. *a.*) which less 6.95, the proportion of carbonic acid in the lime, gives 1.95 remainder. This unites with 1.75 magnesia, and consequently the carbonate of magnesia equals their sum, 3.7.

Accordingly the mineral is composed of

|                        |   |   |       |
|------------------------|---|---|-------|
| Carbonate of lime,     | - | - | 15.9  |
| Carbonate of magnesia, | - | - | 3.65  |
| Silex with mica,       | - | - | 0.20  |
| Red oxide of iron,     | - | - | 0.24  |
|                        |   |   | <hr/> |
|                        |   |   | 19.99 |
| Loss,                  | - | - | 00.01 |
|                        |   |   | <hr/> |
|                        |   |   | 20.00 |

In a 100 parts.

|                        |   |   |        |
|------------------------|---|---|--------|
| Carbonate of lime,     | - | - | 79.5   |
| Carbonate of magnesia, | - | - | 18.25  |
| Silex with mica,       | - | - | 1.00   |
| Red oxide of iron,     | - | - | 01.20  |
|                        |   |   | <hr/>  |
|                        |   |   | 99.95  |
| Loss,                  | - | - | 00.05  |
|                        |   |   | <hr/>  |
|                        |   |   | 100.00 |

In any compound of two given carbonates the proportion of each admits of being determined by the following algebraic formula, when the whole quantity of carbonic acid is ascertained: viz.  $x$ , one of the bases,  $= \frac{m v q - m r q + m r c}{v n - m r}$ .

Let  $q$  denote the quantity of the two carbonates,  $c$  their carbonic acid, then will  $q - c$  denote the sum of the bases.

Again, let  $x$  express one of these bases, then will  $q - c - x$  be the other.

Moreover, as the names of the carbonates are supposed to be known, the proportion of the constituents of each will be found by some standard, as the theoretic composition, the scale of equivalents, &c.

Thus let the salt of which  $x$  is taken as the base be to its base as  $n : m$ . Then as  $m : n :: x : n x \div m$ , an expression for the quantity of the carbonate of  $x$ .

Also, let the remaining salt be to its base as  $r : v$ . Then, as  $v : r :: q - c - x : r q - r c - r x \div v$ , an expression for the quantity of carbonate of  $q - c - x$ .

Thus having found expressions for the two carbonates, and already knowing their sum, viz.  $q$ , we will have the following equation :

$$n x \div m + r q - r c - r x \div v = q.$$

Which divided by  $m$  and  $v$ , gives,

$$v n x + m r q - m r c - m r x = m v q.$$

Which, having all its like terms collected on the same side, gives

$$v n x - m r x = m v q - m r q + m r c.$$

And this divided by the co-efficient ( $v n - m r$ ) of  $x$ , leaves,

$$x = \frac{m v q - m r q + m r c}{v n - m r},$$

Which is the before mentioned general formula.

This formula applied to the example of dolomite experimentally analyzed gives the same result.

20 parts of this mineral, by experiment, yielded 0.2 siliceous with mica and 0.233 red oxide of iron.

These must therefore be deducted from the 20 parts, in order to obtain pure carbonates of lime and magnesia, which carbonates are thus equal to  $20 - 0.433 = 19.567$  parts, and are in the general formula denoted by the letter  $q$ .

The carbonic acid has also been found equal to 8.92 parts, and is expressed by  $c$  in the formula.

The sum of the bases (here lime and magnesia) has already been shewn to be equal to  $q - c$ , that is, in numbers  $= 19.567 - 8.92 = 10.647$ .

And if  $x$  be taken to denote the lime, then it is evident  $10.647 - x$  will be magnesia.

Moreover, as  $x$  is taken for the lime,  $m$  and  $n$  (in the formula must be known. For, according to the scale of equivalents,  $m$  (lime) :  $n$  (carbonate of lime) :: 56 : 100. Therefore, if  $m$  be taken  $= 56$ ,  $n$  will be equal to 100, which is here supposed.

In like manner the proportional values of  $v$  and  $r$  (in the formula) are found, when  $x$  denotes the lime, or  $10.647 - x$  the magnesia.

For, (by the same scale or standard,)  $v$ , the magnesia, :  $r$ , its carbonate, :: 10 : 21.25; consequently,  $v$  being here taken  $= 10$ ,  $r$  will be equal to 21.25.



Having now determined the numeral value of every letter in the general formula, there remains nothing but to substitute them for those letters, and arrive at the known value of the lime ( $x$ ) thus,

$$56 \times 10 \times 19.567 - 56 \times 21.25 \times 19.567 + 56 \times 21.25 \times 8.92 \div 10 \times 100 - 56 \times 21.25 = -1712.4 \div -190 = 9.0.$$

And  $x$ , the lime, being known,  $nx \div m$ , the carbonate of lime, will be equal to - 16.00

|   |   |       |
|---|---|-------|
| $rq - rc - rx \div v$ (carb. of magnesia) | } | 3.567 |
| equal to $q - 16.00$                      |   |       |
| Red oxide of iron, - - -                  |   | 0.233 |
| Silex with mica, - - -                    |   | 0.200 |

---

20.000 parts.

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*Chymical Examination of Schoharite, a new variety  
of Sulphate of Barytes.*

The mineralogical intelligence of an immense bed of sulphate of strontian having been recently discovered in this state, excited a great deal of interest among the learned of America, and has been announced in Europe ; for we find that in the 13th vol. of Thomson's Annals, this news is communicated to the numerous readers of that excellent scientific journal. And as an abundant supply of strontites would make a most desirable addition to our mineralogy, I was solicitous to examine the substance thus called, and no less disappointed to find it prove nothing more than a variety of sulphate of barytes. It was made the subject of analytical instruction to my private pupils, two of whom analyzed it in the laboratory of the college.

*Geographical Locality.*

I learn from Mr. Eaton that this mineral is found in a very extensive bed, at the least three-fourths of a mile long, and sixty feet in thickness, presenting itself along the southern face of a hill of about seventy or eighty feet high. The hill is situated in the town of Carlisle, county of Schoharie, in the state of New-York. It is thirty-four miles west from Albany, and three miles west from Schoharie Kill. (Stream.)

*Geological Position.*

The schoharite, as it is now named by Mr. Eaton, is found in horizontal layers, from half an inch to two inches in thickness. These layers are composed of vertical fibres, attached to each other by their sides. They alternate with thin layers of very soft argillaceous slate. It is very different from the transition slate of the Eastern counties. This, after a few weeks exposure, is changed into common clay.

The schoharite undergoes a remarkable change after being exposed a few months to the air. Its colour changes from bluish to white, and its specific gravity is greatly reduced.

The bed of schoharite rests upon that vast stratum of gray-wacke, which forms the basis rock of most part of the counties of Green, Delaware, and Sullivan, and a considerable portion of Albany and Schoharie. It is overlayed throughout its whole extent with shell limestone.

*Uses.*

One of the Society of Friends, of the name of Baldwin, used this mineral more than two years, as a substitute for borax. He finds it preferable, as a flux, when a high heat is required.

By using it in a pulverized state, as a substitute for clay, he can weld the most refractory steel with the greatest facility. Mr. Eaton personally witnessed some of those facts, and a committee has been appointed by the Troy Liceum of Natural History, for making further experiments in relation to its uses. This committee has not yet reported.

*External Characters.*

Schoharite is of a grayish white colour.

Rubbed over the fibres it feels dry, but at their extremities, where they have been in contact with the layers of clay, they are somewhat unctuous. A little alumine may sometimes adhere to these ends, but it forms no part of the mineral proper.

Its form is small columnar, in straight parallel fibres.

It is semi-hard, not scratched by the nail, but easily scratched by the knife, and the streak is white.

It has neither taste nor smell, does not adhere to the tongue, nor soil paper or the fingers.

It sustained no loss of weight by being kept in a red heat for two hours in a covered crucible, but was rendered very brittle, and easy to be broken in any direction. It also acquired a pearly lustre.

Its sp. gr. by a mean of several trials, with various pieces of unequal weight, is 4.36.

*Analysis of Schoharite, by Shedrick S. Gasque, of  
South Carolina.*

A certain quantity of the mineral which is the subject of this analysis was first reduced to an impalpable powder in an agate mortar.

*a.* Ten grains of the powder were not dissolved by 2 drachms of boiling sulphuric acid of the sp. gr. of 1.82. It required the addition of a third drachm to effect a complete solution. The solution was persistent until the acid had attracted water from the atmosphere, when small crystals were observed to form on the sides of the glass.

A comparative trial was made with an equal quantity of lamellar sulphate of barytes from Sussex County, New Jersey, with a result in no respect different.

In our first essays a considerable portion of mineral was converted into nitrate and muriate, to serve for subsequent examination, after which, and to determine the nature and proportion of its constituent parts,

*b.* 43 decigrammes of the powder were mixed intimately with 25 decigrammes of finely pulverized charcoal and exposed in a covered hessian crucible,



of known weight, to the heat of an air furnace for four hours. Before the contents of the crucible could cool they were poured into a porcelain bason, and diluted with eight ounces of boiling water. Pure nitric acid was afterwards gradually added until the solution tasted sour. The whole was then thrown upon a filter and washed with hot distilled water until it passed tasteless. The crucible had neither lost nor gained weight.

*c.* The filter with its contents and a small additional quantity of charcoal were put into another crucible and treated as in *b*, lest any part of the mineral should have escaped decomposition in that experiment. Dilute nitric acid was again used, the solution filtered and added to the former. Both were carefully and successively concentrated, in the bason which first received them, while they yielded crystals. The quantity obtained was 42 decigrammes, in regular octahedrons.

*d.* The filter last used, with its contents, after having been dried, was consumed in a silver crucible, in melting nitrate of potash, the crucible washed out with distilled water and the fluid thrown on a filter of known weight. This, when thoroughly dried by the heat of boiling water, was found to have gained 2 decigrammes of a white silicious powder, harsh to the touch and gritty between the teeth.

*e.* The alkaline fluid was saturated with nitric acid, and a precipitate obtained, which, when washed and dried in a red heat, in a platina crucible, gave 2 more decigrammes of silica.

*f.* 5 decigrammes of the nitrate *c*, required more than 60 of distilled water for solution at the common temperature.

*g.* The same weight of salt required a still larger proportion of alcohol for solution, at the same temperature.

*h.* Into a test tube containing a portion of the aqueous solution, there was dropped a little barytic water, but it occasioned no precipitate.

*i.* A slip of paper, soaked in the alcoholic solution, burned with a distinct yellow flame.

*k.* Gallic acid caused no change of colour in either the aqueous or alcoholic solution.

*l.* The ferrocyanate of potash occasioned no precipitate or change of colour in either solution.

*m.* This salt partly decrepitated before the blow-pipe, and partly fused into a globule which soon exploded.

The experiments *h*, *i*, *k*, *l*, were repeated with a muriate prepared from the same mineral, but their results were similar.

*n.* The muriate of this mineral crystallized in plates and did not gelatinize on cooling.

These results are conclusive as to the base of this salt being barytes and not strontian. The muriate and nitrate of strontian are easily dissolved; whereas the salts obtained from the mineral under examination proved, at least, 12 times less soluble in our comparative experiments.

Barytic water would immediately precipitate nitrate or muriate of strontian, in virtue of a stronger affinity for these acids, but on barytic salts it can have no effect.

A salt of strontian would not burn with a yellow flame; it burns with one that is blood-red.

The muriate of strontian crystallizes in plates and gelatinizes on evaporation.

The total want of effect of gallic acid and ferrocyanite of potash shew the absence of iron, and the second not causing any precipitate whatever may be ascribed to the entire want of any thing metallic.

42 nitrate of barytes were obtained from 43 of the native sulphate. They should yield 24.817 barytes, because according to the theoretic composition, 100 parts of the nitrate of barytes contain

59.09 parts of barytes, consequently 42 must contain 24.8178.

$$100 : 59.09 :: 42 : 24.8178 ;$$

And again, according to the same composition, 100 parts sulphate of barytes contain 66.1 barytes, therefore 24.8178 parts of barytes must unite with 12.722 sulphuric acid to form 37.54 sulphate of barytes. The sulphate of barytes in the 43 parts of the mineral is therefore

|                                   |   |                    |
|-----------------------------------|---|--------------------|
|                                   |   | 37.54              |
| silex,                            | - | 4.00               |
|                                   |   | <hr/> 41.54 parts. |
|                                   |   | <hr/>              |
| loss,                             | - | 1.46               |
|                                   |   | <hr/> 43.00        |
| or per cent, sulphate of barytes, |   | 87.302             |
| silex,                            | - | 9.302              |
|                                   |   | <hr/> 96.604       |
| loss,                             | - | 3.396              |
|                                   |   | <hr/> 100.000      |

*Analysis of Schoharite, by John Emmet of New-York.*

*a.* Ten grammes of the mineral, first reduced to an impalpable powder in an agate mortar, were intimately mixed with 30 grammes of fine dry charcoal, inclosed in a covered crucible and exposed to the heat of a wind-furnace for three hours. After which the contents were turned into a bason and diluted with boiling water—a strong smell of sulphur ascended with the vapour. Presently the whole was washed into a filter and the clear solution of hydrosulphuret of barytes collected.

*b.* To this there was added pure nitric acid, until its taste predominated. Lac sulphuris appeared, and 25 centigrammes of sulphur were collected on a filter.

*c.* The solution which passed the filter was set by to crystallize and yielded successively 9·82 grammes of clear crystals of the nitrate of the base, (barytes as was proved in Mr. Gasque's analysis.)

*d.* These crystals were dissolved in distilled water and diluted sulphuric acid was dropped in until there ceased to be a precipitate. The regenerated



sulphate of barytes was collected, dried, and the excess of sulphuric acid driven off in a red heat in a small platina alembic. Its weight, without removal, was found to be 9.1 grammes. This result corresponds with the composition of the nitrate.

According to Richter, 100 parts nitrate of barytes contain 61 base ; therefore, 9.32 must contain 5.99, or nearly 6 ; consequently 10 of the mineral contained 6 barytes. Fourcroy and Berzelius found in 100 pure sulphate of barytes 66 base, therefore, 6 barytes will form 9.1 sulphate, which is the same as found by experiment *d*, and  $9.1 - 6$  gives 3.1 for the acid.

*e.* What remained on the filter in experiment *a*, besides charcoal, contained all that the acid did not take up. On this account the filter and it together, after having been dried, were put into a crucible of pure silver, and burnt by the successive addition of a few grains of nitrate of potash. In this way nearly 5 decigrammes of silex were recovered. But on the repetition of this process, and, in consequence of using too much nitre, the crucible, a thin one, began to melt, and any thing further that might be obtained was lost.

According to this analysis, schoharite is composed

of sulphate of barytes and silex only, and of these in the following proportions :

|                 |       |   |   |       |
|-----------------|-------|---|---|-------|
| barytes,        | 6     | } | - | 60    |
| sulphuric acid, | 3.1   |   | - | 31    |
| silex,          | 0.5   |   | - | 5     |
|                 | <hr/> |   |   |       |
|                 | 9.6   |   |   | 96    |
| loss,           | - .4  |   | - | 4     |
|                 | <hr/> |   |   | <hr/> |
|                 | 10    |   |   | 100   |

Klaproth has analyzed a mineral which he calls granular baroselenite from Peggau in Stiria. The description he gives agrees very well with this from New-York.—The sp. gr. of his 4.38, that found here 4.36; neither lost weight by ignition; both were brittle after being heated, and assumed a beautiful white and shining appearance. But that from Peggau is granular, this from Schoharie is fibrous.

The stirian sulphate of barytes yielded, in the analysis of Klaproth, barytes, - 60

dry sulphuric acid, - 30

silex, - 10

---

100

Or, stating the composition of sulphate in the proportion of 60 base and 30 acid as more correct; these two sulphates will appear to differ in nothing but the mere form of their aggregation.

*Experimental enquiry into the solubility of corrosive sublimate in spirits of turpentine, by Thomas Andrew Duffy of New-York.*

A profuse salivation, followed by mortification of the fauces that terminated fatally, was supposed to arise from corrosive sublimate mixed in spirits of turpentine, with which the patients bed had been cleaned. In order to determine if this could be the case, I made the following experiments.

*a.* 5 grammes of corrosive sublimate were triturated with 10 decagrammes of spirits of turpentine of the specific gravity of  $\cdot 870$ , and then put into a phial which was shaken at intervals during several hours; after two days repose, all that could not be dissolved had completely settled to the bottom; the solution was perfectly transparent and necessarily saturated.

*b.* A minim glass was filled with a portion of this solution up to a certain mark, and, after subtraction of the weight of the glass, that of its contents was found to be 6 grammes, 6 decigrammes.

*c.* The tube was next emptied, carefully washed out with alcohol, dried, and filled precisely to the same mark with pure spirits of turpentine, part of that used for making the solution *a.* It was now

put into the scales and weighed exactly 6 grammes, 5 decigrammes.

*d.* Two thirds of the remainder of the saturated solution *a* was introduced into a small retort, a receiver adapted, and about one-half distilled off by a gentle heat. Now the same tube was again filled to the mark with the distilled spirit, and it weighed, with the utmost nicety 6 grammes, 5 decigrammes.

*e.* The effect of sulphuretted hydrogen was next tried, and, in order to have it of the greater purity, it was prepared from sulphuret of antimony, in fine powder, and strong muriatic acid; one part of the former and five of the latter were put into a small tubulated retort, having a bent tube adopted to its extremity, the other end of which tube dipped into a glass containing a portion of the distilled fluid *d*; a gentle lamp heat was applied and gas generated, but it produced no manner of change in the contents of the glass.

*f.* The gas issuing from the retort was now made to pass in the same manner through some of the solution *a*, and in a very short time it turned it yellow; speedily after there was deposited a precipitate of the same colour.

It is proved in these trials, experiment *b*, that spirits of turpentine do not dissolve more than 1.53

per cent of corrosive sublimate. It follows from experiment *d*, that no part of this same rises in distillation. *e* corroborates the conclusion in *d*, and it is further confirmed by the very distinct yellow precipitate caused by the sulphuretted hydrogen where there was ever so little corrosive sublimate present in the solution.

As relates to the death which occurred, it is clearly not imputable, in the remotest degree, to the alleged cause ; for no particle of the mercurial salt could have been volatilized from the bed, or inhaled by the patient.

FINIS.





## ERRATA.

- Page 12, in lines 3, 4, 5, from the bottom, for 1000 read 1·000.  
 15, line 8 from bottom, dele *and*.  
 18, lines 1 and 2 at top, for 1000 read 1·000.  
     line 1 from top, for 0·694 read 0·694.  
 36, line 3 from top, for 109·9 read 108·9.  
 37, line 8 from top, for 151·3 read 181·3.  
     line 21, for the proportion  $100 : 154 :: 1 : 1·54$ , read as  $154 : 100 :: 2 : 1·29$ ; and for  $39·38 : 60·62 :: 1 : 1·54$ , read  $60·62 : 39·38 :: 2 : 1·29$ .  
 40, line 2 from top, for *tritrooxide* read *trioxide*.  
     line 4 from top, for *for* read *from*.  
 43, line 3 from top, after sulphuric acid insert *with carbonic acid*.  
     line 9 from top, for 76 read 76.  
 46, line 5 from bottom, insert *of* before Klaproth.  
 48, line 15 from the top, after 13·6 insert *oxygen*.  
 49, line 3 from top, for 8·785 read 8·875.  
 50, line 4 from top, for 3 read 8.  
 54, line 15 from top, after combines read *to form similar oxides*.

## *Appendix.*

- Page 4, line 6 from bottom, for 950 read 953.  
 8, line 7 from top, for 357 read 367.  
 10, line 2 from top, for 23 *decigrammes* read 20 *centigrammes*.  
     line 4 from top, for *flacculent* read *flocculent*.  
     line 6 from top, for *decigrammes* read *centigrammes*.  
 12, line 8 from bottom, before carbonates read *anhydrous*.  
 27, line 11 from top, for 10 *decagrammes* read 80 *grammes*.



*Mr. Robert G. Schenck*  
*in paper*

EXPOSITION  
OF THE  
ATOMIC THEORY  
OF  
CHYMISTRY:  
AND THE  
DOCTRINE OF DEFINITE PROPORTIONS.

BY  
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PROFESSOR OF CHYMISTRY AND MATERIA MEDICA IN THE COLLEGE OF  
PHYSICIANS AND SURGEONS OF THE UNIVERSITY OF  
THE STATE OF NEW-YORK.

WITH AN APPENDIX OF CHYMICAL EXERCISES,  
BY THE PUPILS OF THE LABORATORY, &c.

NEW-YORK:  
PRINTED BY GRATTAN AND BANKS,  
*Corner of Nassau & Spruce Streets.*

1819.



